Space between buildings as a means of preventing the spread of fire. Report D: concluding study on three regions in Vancouver

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DIVISION OF BUILDING RESEARCH

SPACE BETWEEN BUILDINGS AS A MEANS OF PREVENTING THE SPREAD OF FIRE

Report D -- Concluding Study on Three Regions in Vancouver

by

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A Joint Project of the School of Architecture
and the Graduate Program in Community and Regional Planning,
University of British Columbia
and the
Division of Building Research, National Research Council

Internal Report No. 283
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OTTAWA

May 1964

The late Professor Fred Lasserre, as Director of the School of Architecture at the University of British Columbia, was one of the original sponsors of this research project. His contribution is remembered appreciatively by all connected with this Report.

R. F. Legget

PREFACE

This report is one of a series of four which are concerned with space between buildings as a means of preventing the spread of fire, which, in turn forms part of the main project "Performance Standards for Space and Site Planning for Residential Development."

This project has been undertaken for the Division by the School of Architecture at the University of British Columbia. Two reports have already been issued: An Annotated Bibliography on Performance Standards for Space and Site Planning for Residential Development (NRC 6442) and DBR Internal Report No. 273, "A Study of Performance Standards for Space and Site Planning for Residential Development." The latter contains a discussion of the factors that determine the spacing of residential buildings. This present series of four reports, deals with one of these factors - - fire. The other factors, including daylight, noise and privacy, will be dealt with in subsequent reports. When all of these reports are issued, they will form a complete evaluation of all the conditions that must be considered in the planning of residential areas in Canada.

The authors of the first three reports in this series are on the staff of the University of British Columbia. Professor Oberlander, besides his duties on the staff of the School of Architecture, is Head of the Graduate Program in Community and Regional Planning; Professor Gerson, at the time these reports were written, was Acting Director of the School of Architecture, and Mr. Goldsworthy was research assistant to the Project. This fourth report has been prepared by Professor Oberlander and R. Stirling Ferguson, Head of the Building Standards Section of the Division of Building Research. In this report they have explained how the regulations in the National Building Code were interpreted in the first three studies of regions in Vancouver with respect to building configurations not considered in the Code.

The present Head of the School of Architecture at UBC, Professor Henry Elder, has shown much interest in this project which was initiated under the direction of his predecessor, the late Professor Fred Lasserre.

This information is being issued in the Divisional series of internal reports so that those responsible for the work can have the benefit of informed comments prior to publishing in a more formal way. Comments will, therefore, be welcomed and should be sent either to Professor Oberlander at UBC or to the writer in Ottawa.

Ottawa
May 1964

R. F. Legget
Director, DBR/NRC

FOREWORD

The unprecedented volume and suburban concentration of post-war housing has revealed many inadequacies in the use of traditional space and location standards as a basis for achieving a high quality of residential communities. In most instances, such standards have merely allowed housing to be built in a mechanically neat and orderly fashion. Standards that are more flexible and imaginative seem essential if the next flood of housing is to add more to urban Canada than further volume of accommodation.

Following the war, cities and towns became increasingly aware of the value of controlling, through zoning and building bylaws, the individual's use of his land for the benefit of the whole community. Such bylaws usually restrict development with absolute yard and height limitations designed to achieve standards of safety, health, amenity and aesthetic appearance. The absolute and one-dimensional nature of these limitations, however, has usually resulted in a monotonous and rigid spacing of buildings.

The main purpose of this research project is to demonstrate that adequate space around and between buildings for functional and aesthetic purposes can be achieved with greater flexibility through controls usually referred to as "performance standards." Such standards determine space between and around buildings by the variety of functions they perform and in relation to the size of land and buildings in a given situation.

The value and ease of administration of the performance standards has already been demonstrated in industrial and commercial development.

This report forms a portion of a continuing study. Following a study of the literature (14) a preliminary report was prepared on the factors which determine the spacing of residential buildings (15). This comprised the full range of community objectives - fire, daylight, air, privacy, view, outdoor space, traffic and noise.

A more concerted study of prevention of fire spread followed. This field of investigation was chosen because information is more readily available than for other community objectives. Means of fire prevention based on performance have already been devised and these are applied in Canada's National Building Code. Using the appropriate requirements of the National Building Code of Canada 1960 as a basis, field surveys of three developments in Metropolitan Vancouver were made*. The particular aim was to appraise the Code requirements.

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* DBR Internal Reports Nos. 280, 281, and 282, by H. P. Oberlander, W. Gerson and R. D. Goldsworthy

This study proved to be most rewarding. Since it was the first study of its kind, the results could not have been anticipated. Familiarity with the method, however, has led to confidence that the performance method will in the end provide the desired result.

It is expected that this fourth report will be of special interest to code writers and administrators since it investigates in detail the many unusual circumstances which arise and which make the application of a seemingly simple regulation complicated. It explains in detail how the authors interpreted the regulations with respect to building configurations which the code writers had, for quite valid reasons, not allowed for. A study of this report by those who are technically concerned can do much to further the understanding and improvement of performance methods of control of fire spread between buildings.

This is a sufficient reward for the work which has been done; yet it satisfies but one of the two objectives of the study. The second one is more far-reaching. It is the eventual attainment of methods to control space between buildings in a manner that will provide safety and at the same time the necessary flexibility to achieve the greatest utilization of space and the greatest freedom to express, through design, the fulfilment of space use.

Architects and other designers who read this report will begin to read into it a new more definite vocabulary of design. A screen, opened or closed, becomes more than an aesthetic device because it can serve in a measurable capacity as a fire break. One is encouraged to think that its value as a sound barrier can be determined quantitatively as well. Setbacks, window openings and other factors are enriched with added meaning in the fire spread sense. In this fusion of science and architecture the germ of a new idiom may be present. Even so, it is only a germ. The goals toward which this work leads are still a long way off.

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SPACE BETWEEN BUILDINGS AS A MEANS OF PREVENTING THE SPREAD OF FIRE

Report D -- Concluding Study on Three Regions in Vancouver

by

H. P. Oberlander and R. S. Ferguson

Reports A, B, and C* contain the on-site measurements pertaining to distance separations for three blocks of buildings which were surveyed in Metropolitan Vancouver. In the case of each building examined the actual distance was compared with a distance calculated on a performance basis as applied in the National Building Code 1960. This exercise was useful in two ways: it revealed discrepancies in the actual and calculated distances and it served as the first documented test of the performance method as applied in the National Building Code. Findings with respect both to the distances and the application of the method may be found complete in Reports A to C. From these, readers may draw their own conclusions.

The authors wish to add their observations to the information in the preceding three reports and have placed these together in this separate report since these observations are based on experience with all rather than any one of the study areas. The first observations are on the distance separations and the second observations are on the method used.

OBSERVATIONS ON DISTANCE SEPARATIONS

In the central built-up area (Report A, DBR Report 280), indications are that the separation between buildings did not prevent fire spread but by the expedient of enclosing the stair shafts in the larger buildings this danger could be almost entirely overcome. Again in the suburban areas where a new group of single houses was examined, it was shown that the measured distances were quite ample and in nearly every case excessive. Here then is an example in the field of prevention of fire spread where the minimum has not become the maximum. Comparing the central and outlying study areas, it is

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* DBR Internal Reports 280, 281, and 282.

apparent that there is no consistency of design safety against fire spread. This is a small sample but, since each of these two areas is typical, the observation has some significance.

Both areas were developed from the viewpoint of economic gain and both were developed at times when the land was subject to controls to prevent fire spread.* Had both economics and fire safety been important determinants and had an adequate method of preventing fire spread been in effect, one can conclude that the resulting designs would have been different. The buildings in the central study area would have been safer and those in the outlying area would have shown greater conservation of land.

With regard to the latter area, the more generous provision of space was obviously for reasons other than fire safety since the distance exceeded the required distances in effect when the buildings were built. From the viewpoint of controls, there is no quarrel with this and it is perhaps heartening that the minimum has been exceeded voluntarily. The real concern is that when space does get tight, as in the central study area, there is no way, other than with performance standards,to provide minimum safety. In other words, up to the present, it seems that the desire for space rather than the existing controls has been effective in providing protection against fire spread.

Turning to economics one could criticize the disposition of space in both study areas without even knowing the objectives of the spaces other than for fire protection. Casual observation on the basis of good design practice indicates that these spaces are not tailored to some special use. If this is true, it is quite probable that the design is not the most convenient or economic. This is a matter, however, which is beyond the immediate purpose. It is mentioned, in the first place, to suggest that there was no more important reason that would justify an arbitrary standard of fire safety, and, second, to remind the reader that this study of fire safety is only part of a larger study concerned with the measurable aspects of space around buildings. Since minima and maxima have been discussed, it might be pointed out here, if it is not already apparent from the foregoing, that what is hoped for is an optimum which would embrace safety, economics, and utility.

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* A graphic presentation of those controls has been prepared and will soon be published for comparative purposes.

Although only a fraction of the whole problem has so far been examined, there is encouraging evidence that a rational approach based on performance can be a more precise determinant for design. If this approach can be utilized to the full, design can be more exact thereby eliminating chance hazards on the one hand and creating the opportunity to conserve space on the other, and so allow for full use with safety at low cost.

OBSERVATIONS ON THE PERFORMANCE METHOD

Study area No.3 (Report C, DBR Report 282) highlights the second aspect in which this report was useful. It reveals in a convincing way that the performance method employed in the National Building Code of Canada is still in its embryo stages and that it could benefit from further study. The premise for this system of control is theoretical. The variables it employs are those directly related to the fire hazard. This explains its superiority over rule of thumb methods. The distance changes as the fire hazard changes. In the rule of thumb system the distance remains constant while the hazard changes with the result that the distance is rarely correct for fire safety. There is usually either too little or too much. On the other hand, the performance method is accurate only if it can be adapted to the situations which are likely to arise. What forms of design it should be adapted to and how are difficult to foresee and can only finally be proved in practice. In this respect the field studies were most useful.

The Code assumes that buildings are disposed horizontally to each other. Study area No. 3 was on sloping ground. It showed clearly that consideration should be given in the method to buildings which are disposed vertically one to another. This and other problems caused by design variations will be examined in detail in Part 2.

PART 2

This part is a discussion of the mechanics of applying performance standards to the prevention of fire spread between buildings. In the course of the field work, and as was expected, a number of configurations were encountered which varied from the standard situation (a plane surface with uniformly distributed openings) for which the Code method was devised. The main variations are:

1. The treatment of length and height of wall and area of openings depending on how the openings are dispersed. The important matter here is the assumption of a height and area related to the openings rather than the wall dimensions when the windows are grouped or dispersed unevenly. This assumed portion of the wall is known as the enclosing rectangle.
2. Height of the roof.
3. Wall offsets.
4. Difference in ground elevation between adjacent buildings.
5. The facing walls of adjacent buildings not parallel.
6. Structural baffles.

These six special design problems are discussed in order but first some word of explanation is warranted concerning the Table of Separation Distances (Figure 1) and the "Limiting Distance" since these are not identical with those found in the National Building Code.

Table of Separation Distances

The table of separation distances used in this report (Figure 1) is adapted from the table in DBR Report No. 187 by J.H. McGuire (20). This is the original reference for the tables in the National Building Code. It differs in form from the one in the Code but in every essential respect the content is the same. Each uses the same dependent variables but the table in DBR Report No. 187 derives minimum separation distances whereas in the Code this is one of the indices and percentage of window

FIGURE 1

SEPARATION FROM BUILDING TO BUILDING

Width of Compartment ft	% of window openings	Height of compartment, ft									
		10	20	30	40	50	60	70	80	90	100
30	100	66	96	124	142	156	170	184	196	208	218
	80	58	86	110	126	140	154	164	174	184	190
	60	48	74	92	108	120	130	140	148	154	160
	40	39	56	70	82	92	100	108	114	120	124
	20	24	36	48	54	58	62	66	68	70	70
40	100	76	112	142	162	182	198	214	228	242	254
	80	68	102	126	146	164	180	194	206	216	226
	60	56	86	108	124	138	152	164	174	182	190
	40	42	66	82	98	110	120	128	136	142	148
	20	26	40	54	62	68	74	78	82	86	86
50	100	86	124	156	182	204	226	242	258	274	286
	80	74	110	140	164	182	200	216	230	244	256
	60	60	94	120	138	154	170	184	196	208	216
	40	46	74	92	110	122	134	144	152	160	166
	20	26	44	58	68	76	84	90	96	100	102
60	100	94	138	170	198	226	248	266	284	302	320
	80	80	122	154	180	200	220	238	254	268	282
	60	66	102	130	152	170	188	204	214	226	238
	40	48	80	100	120	134	146	158	170	178	184
	20	26	46	62	74	84	92	100	106	110	114
70	100	102	146	184	214	242	266	290	310	328	346
	80	86	130	154	194	216	238	256	274	292	308
	60	70	110	140	164	184	202	216	232	244	258
	40	50	86	108	128	142	158	174	184	194	202
	20	26	48	66	78	90	100	106	114	120	126
80	100	106	154	196	228	258	284	310	332	352	370
	80	90	138	174	206	230	254	274	294	312	328
	60	74	118	148	174	196	214	232	248	262	276
	40	52	90	114	136	152	170	184	194	206	216
	20	26	48	68	82	96	106	114	122	130	136
90	100	110	164	208	242	274	302	328	352	372	392
	80	94	146	184	216	244	268	292	308	330	338
	60	78	120	154	182	208	226	244	262	278	292
	40	54	92	118	142	160	178	194	206	218	230
	20	26	50	70	86	100	110	120	130	138	142
100	100	112	172	218	256	286	320	346	370	392	414
	80	96	150	190	226	256	282	308	328	338	366
	60	80	122	160	190	216	238	258	276	292	308
	40	54	94	124	148	166	184	202	216	230	242
	20	26	50	70	86	102	114	126	136	144	152
120	100	118	184	236	276	314	348	378	404	428	450
	80	102	158	208	246	278	306	334	358	380	402
	60	80	128	172	204	236	260	282	302	322	338
	40	54	98	134	158	180	202	220	236	252	268
	20	26	50	70	90	106	118	130	142	154	166

openings is derived. An examination of the two tables will reveal other similar differences (see Figures 2 and 3).

These differences result in each table being more accurate than the other in some respects. Each is accurate where the values in the indices are those referred to. Where it is necessary to interpolate between these values, some error is present. Because of this the table in the Code is more convenient and more accurate where the distance from the lot line is known. This is particularly the case where buildings are small and situated close to the lot line. The other table from DBR Report No. 187 is more accurate in the case of larger buildings located further away and is more convenient where the percentage of window opening is known and it is the distance that is to be derived. These conditions are in fact the ones which generally prevail in the situations to be discussed in this part of this report. . Where the buildings are very small such as is the case with private single family dwellings neither table is very accurate. This is a special case which will probably be treated separately in the future.

Limiting Distance

Both the tables (Figures 2 and 3) give the distance from the building face to the lot line. The table used in this part (Figure 1) differs from both because the distances have been doubled to equal the total distance between two adjacent buildings. This was done even though it departs from the method used in the Code because it eliminates a serious error which develops with the Code system in determining the required space between two buildings which vary greatly in size. The Code method is the only known method that is satisfactory in a legal and administrative sense. The importance of this is acknowledged but it is a matter which is of no concern in this chapter as this present study deals solely with the technical problem. It is not therefore that the legal question is of less importance but rather that first things must be dealt with first. The decision to use the whole rather than half the distance affects the examples where more than one building is involved. It does not affect the methods that are developed for determining the enclosing rectangle.

Using the modified table of separation distances and the limiting distance as explained above, the application of the performance method to six different design situations is discussed.

Figure 2

SEPARATION FROM BUILDING TO BUILDING

Width of Compartment (feet)	% of window openings	Height of compartment (feet)									
		10	20	30	40	50	60	70	80	90	100
30	100	33	48	62	71	78	85	92	98	104	109
	80	29	43	55	63	70	77	82	87	92	95
	60	24	37	46	54	60	65	70	74	77	80
	40	19	28	35	41	46	50	54	57	60	62
	20	12	18	24	27	29	31	33	34	35	35
40	100	38	56	71	81	91	99	107	114	121	127
	80	34	51	63	73	82	90	97	103	108	113
	60	28	43	54	62	69	76	82	87	91	95
	40	21	33	41	49	55	60	64	68	71	74
	20	13	20	27	31	34	37	39	41	43	43
50	100	43	62	78	91	102	113	121	129	137	143
	80	37	55	70	82	91	100	108	115	122	128
	60	30	47	60	69	77	85	92	98	104	108
	40	23	37	46	55	61	67	72	76	80	83
	20	13	22	29	34	38	42	45	48	50	51
60	100	47	69	85	99	113	124	133	142	151	160
	80	40	61	77	90	100	110	119	127	134	141
	60	33	51	65	76	85	94	101	107	113	119
	40	24	40	50	60	67	73	79	85	89	92
	20	13	23	31	37	42	46	50	53	55	57
70	100	51	73	92	107	121	133	145	155	164	173
	80	43	65	77	97	108	119	128	137	146	154
	60	35	55	70	82	92	101	108	116	122	129
	40	25	43	54	64	72	79	87	92	97	101
	20	13	24	33	39	45	50	53	57	60	63
80	100	53	77	98	114	129	142	155	166	176	185
	80	45	69	87	103	115	127	137	147	156	164
	60	37	59	74	87	98	107	116	124	131	138
	40	26	45	57	68	76	85	92	97	103	108
	20	13	24	34	41	48	53	57	61	65	68
90	100	55	82	104	121	137	151	164	176	186	196
	80	47	73	92	108	122	134	146	154	165	169
	60	39	60	77	91	104	113	122	131	139	146
	40	27	46	59	71	80	89	97	103	109	115
	20	13	25	35	43	50	55	60	65	69	72
100	100	56	86	109	127	143	160	173	185	196	207
	80	48	75	95	113	128	141	154	164	169	183
	60	40	61	80	95	108	119	129	138	146	154
	40	27	47	62	74	83	92	101	108	115	121
	20	13	25	35	43	51	57	63	68	72	76
120	100	59	92	118	138	157	174	189	202	214	225
	80	51	79	104	123	139	153	167	179	190	201
	60	40	64	86	102	118	130	141	151	161	169
	40	27	49	67	79	90	101	110	118	126	134
	20	13	25	35	45	53	59	65	71	77	83

FIGURE 3

SEPARATION FROM LOT LINE

Area of Exposed Building Face, sq ft	Ratio L/H or H/L*	LIMITING DISTANCE, ft									
		4	6	10	15	20	30	50	70	100	140
		Permissible Area of Unprotected Openings in Exposed Building Face, per cent									
less than 300	less than 3:1	5	7	15	32	57	100	100	100	100	100
	3:1 to 10:1	6	9	18	34	63	100	100	100	100	100
	over 10:1	9	13	25	44	68	100	100	100	100	100
300 and over but less than 400	less than 3:1	5	6	12	23	41	65	100	100	100	100
	3:1 to 10:1	6	8	15	27	45	80	100	100	100	100
	over 10:1	8	11	20	35	55	100	100	100	100	100
400 and over but less than 500	less than 3:1	4	6	11	21	34	73	100	100	100	100
	3:1 to 10:1	5	7	13	23	37	75	100	100	100	100
	over 10:1	7	10	18	31	47	87	100	100	100	100
500 and over but less than 600	less than 3:1	4	6	10	18	19	60	100	100	100	100
	3:1 to 10:1	5	7	11	19	32	70	100	100	100	100
	over 10:1	7	10	17	28	41	80	100	100	100	100
600 and over but less than 800	less than 3:1	4	5	8	15	23	50	100	100	100	100
	3:1 to 10:1	5	6	10	16	25	52	100	100	100	100
	over 10:1	7	8	14	23	35	60	100	100	100	100
800 and over but less than 1000	less than 3:1	4	5	7	12	19	40	100	100	100	100
	3:1 to 10:1	5	5	9	14	22	44	100	100	100	100
	over 10:1	6	8	13	21	30	50	100	100	100	100
1000 and over but less than 1500	less than 3:1	3	4	6	9	14	28	73	100	100	100
	3:1 to 10:1	4	5	8	11	16	31	75	100	100	100
	over 10:1	6	7	11	17	23	40	87	100	100	100
1500 and over but less than 2500	less than 3:1	3	3	5	7	10	19	44	88	100	100
	3:1 to 10:1	3	4	6	9	12	21	48	90	100	100
	over 10:1	5	7	9	13	17	34	50	100	100	100
2500 and over but less than 3500	less than 3:1	3	3	4	6	8	14	34	62	100	100
	3:1 to 10:1	3	4	6	8	10	16	47	67	100	100
	over 10:1	5	6	8	11	15	23	50	73	100	100
3500 and over but less than 5000	less than 3:1	2	3	4	5	7	11	25	44	88	100
	3:1 to 10:1	3	3	5	7	8	13	35	48	90	100
	over 10:1	5	6	7	10	12	19	38	50	100	100
5000 and over	less than 3:1	2	2	3	5	6	8	19	34	50	100
	3:1 to 10:1	2	2	4	6	7	10	22	37	55	100
	over 10:1	4	5	7	9	10	15	30	47	60	100
Column 1	2	3	4	5	6	7	8	9	10	11	12

* L = length of building face; H = height of building face.

SITUATION 1: HEIGHT OF WALL, LENGTH OF WALL, AREA OF OPENINGS

(a) Compartmentation of the Building

It was shown in the DBR Report No. 280 that it is desirable to subdivide the building into compartments by means of fire-resistive walls and floors. This makes it possible to assume that, for the purpose of space separation calculation, each subdivision is a separate building, thus each compartment can be treated as a separate radiator.

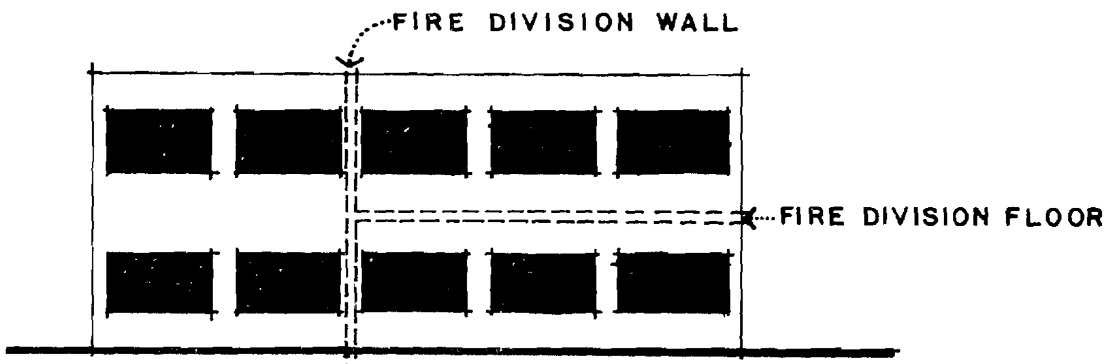

Figure 4

(b) Distribution of Openings

It is important to remember that openings are considered to be the radiating areas. An opening may be defined as any portion of the wall not having the required fire resistance. This is usually a window or a door since, for our purpose, we have assumed that the exterior walls resist the passage of fire until the fire department arrives.

The tables of separation prepared by the Division of Building Research are based on the assumption that the openings in the wall are infinitely small and are distributed uniformly. In many cases this approach is not applicable, for instance, where the openings are concentrated in only one portion of the facade. Here it is more accurate to deal only with the localized area having the high concentration.

There are two alternative methods available to cope with this problem. One is contained in "Housing Standards, 1962" Supplement No. 5 to the National Building Code of Canada (24) and the other in "Fire and Space Separation" (31) by G. J. Langdon Thomas. The Housing Standards state:

> "Where the windows are distributed nonuniformly over the face of a building and there is a glazed area that has a width exceeding the limiting distance, the area of wall face to be considered shall be bounded by the ends of the glazed area and
>
> a) finished grade,
>
> b) a floor that is a one-hour fire separation, or
>
> c) the ceiling of the uppermost floor area."

Note, however, that the "limiting distance" referred to is the separation to the lot line, and hence is approximately one-half the separation from the building to its neighbouring building.

The second method is known as the "enclosing rectangle" concept and is described in the following section.

(c) Enclosing Rectangle

The percentage of openings in a wall may be expressed in terms of the rectangle that encloses all the openings in the area of exposure hazard. Such a rectangle is known as the "enclosing rectangle." The openings may be spaced across the facade as a number of groups of openings. It is necessary, therefore, to use another term - the "over-all enclosing rectangle."

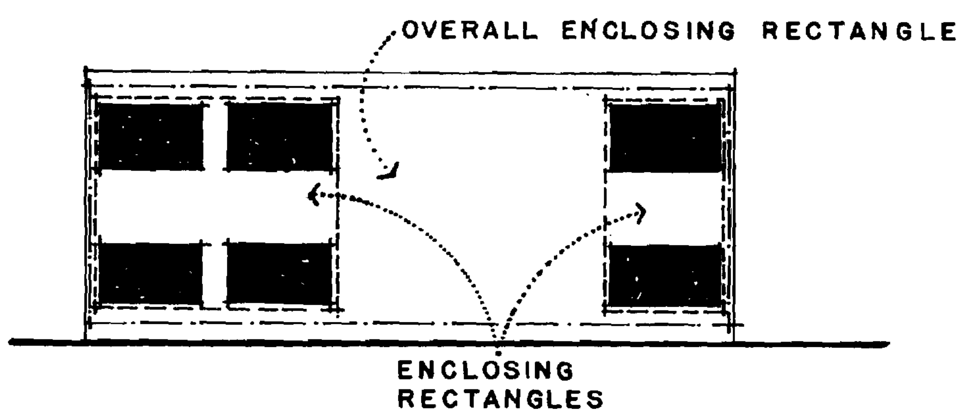

Figure 5

In the analyses in the previous reports the method used was the one that gave the maximum separation requirements.

(d) Staircase Enclosures

An enclosed stair is one which is contained within suitably fire-resistive walls so that it will not permit a fire, having its origin in one storey of the structure, to spread to other storeys. An open stair is one which will permit the spread of fire vertically through the structure.

It is important that enclosed stairs need not be considered as part of the wall for the purpose of space separation calculations.

(e) Recess or Setback in the Wall of 5 ft or Less

Since a facade is often broken up into a number of planes it is necessary to determine what can be considered a plane surface. A convenient assumption is that any plane set back 5 ft or less from the main elevation may be considered, for the purpose of the calculations, to lie on the same plane as the face of the building. This assumption is tested in the analyses of Field Survey Area No. 1 (DBR Report 280) and found to be reasonable. That is, it makes no appreciable difference to the separation requirements whether the facade is analyzed as a number of planes or as one plane located on the plane of reference.

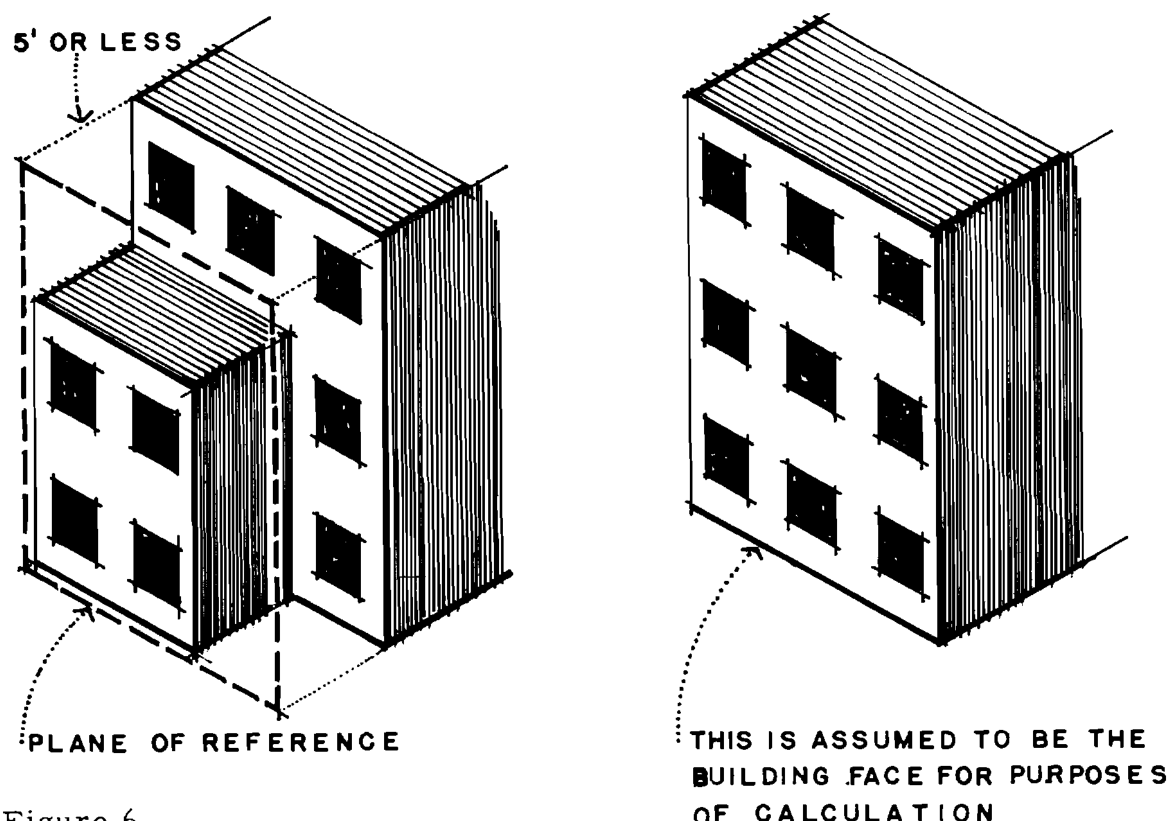

Figure 6

(f) Recess or Setback in the Wall of More than 5 ft

Setbacks

A setback in the facade reduces the radiation hazard it presents to the exposed building and thus a reduction in the separation requirements is possible. This is achieved by considering the elevation in two portions: that part on the plane of reference and the setback portion.

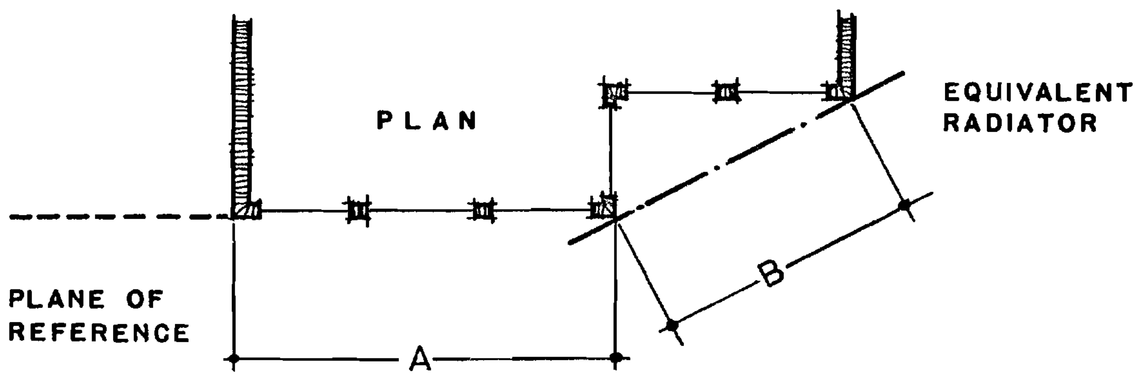

Figure 7

The portion on the plane of reference is dealt with in the normal manner. The next step is to set up an "equivalent radiator." That is, a line joining the external angles as shown in Figure 7. The openings are assumed to lie on this plane and the percentage of openings within the area are assumed to be the equivalent radiator. The required spatial separation can then be assessed from the table.

Recess with Openings on Three Sides

The basic assumption here is that all the openings in the recess are radiating at the aperture. Analyses may then proceed as before, remembering that the recess may create a local concentration of openings necessitating an increase in the separation requirements at that point.

Recess with Openings in the Rear Wall Only

Calculation of the separation requires the use of a simple mathematical formula; the procedure is as follows. First, determine the separation assuming that all openings are radiating at the aperture. The fact that some openings are set back from the plane of reference will reduce the intensity of radiation from the elevation and this reduction may be assessed from the following formula adapted from "Fire and Space Separation" (31)

$$f = \left[\frac{s}{s + r} \right]^2$$

where

s is the first separation requirement, in ft,
r is the depth of the recess in ft, and
f is the factor by which the openings may be reduced.

Knowing s and r , f may be calculated. The area of openings in the recess is then deduced by the resulting factor and the calculations repeated to give the final separation requirements.

(g) Non-fire-resistive Projections into the Space

Separation is defined as open and unobstructed space. Any element that has a fire resistance of less than three-quarters of an hour and which projects into the space between the two buildings will facilitate the spread of fire from the exposing to the exposed building.

In the analyses contained in the previous reports it is assumed that the required spatial separation must be measured from the extremity of such a projection. This seems to be an unnecessary hardship. An alternative method assumes that there is no non-fire-resistive element within 4 ft of the exposed building. This is derived from the "Housing Standards 1962" (24) which state that an element may be 2 ft from the boundary of the lot without necessarily having non-combustible cladding. Doubling this figure will give the approximate relation from building to building rather than from the building to the boundary of the lot. It may be that some other assumption is necessary but this one is used.

SITUATION 2: HEIGHT OF ROOF

The roof need only be considered in the calculations if it contains a habitable space and has openings permitting radiation to endanger the exposed building. The roof space, therefore, is considered as an extension of the wall.

SITUATION 3: OFFSETS

Figure 8 shows that a reduction in the separation requirements is possible if the buildings are offset sufficiently.

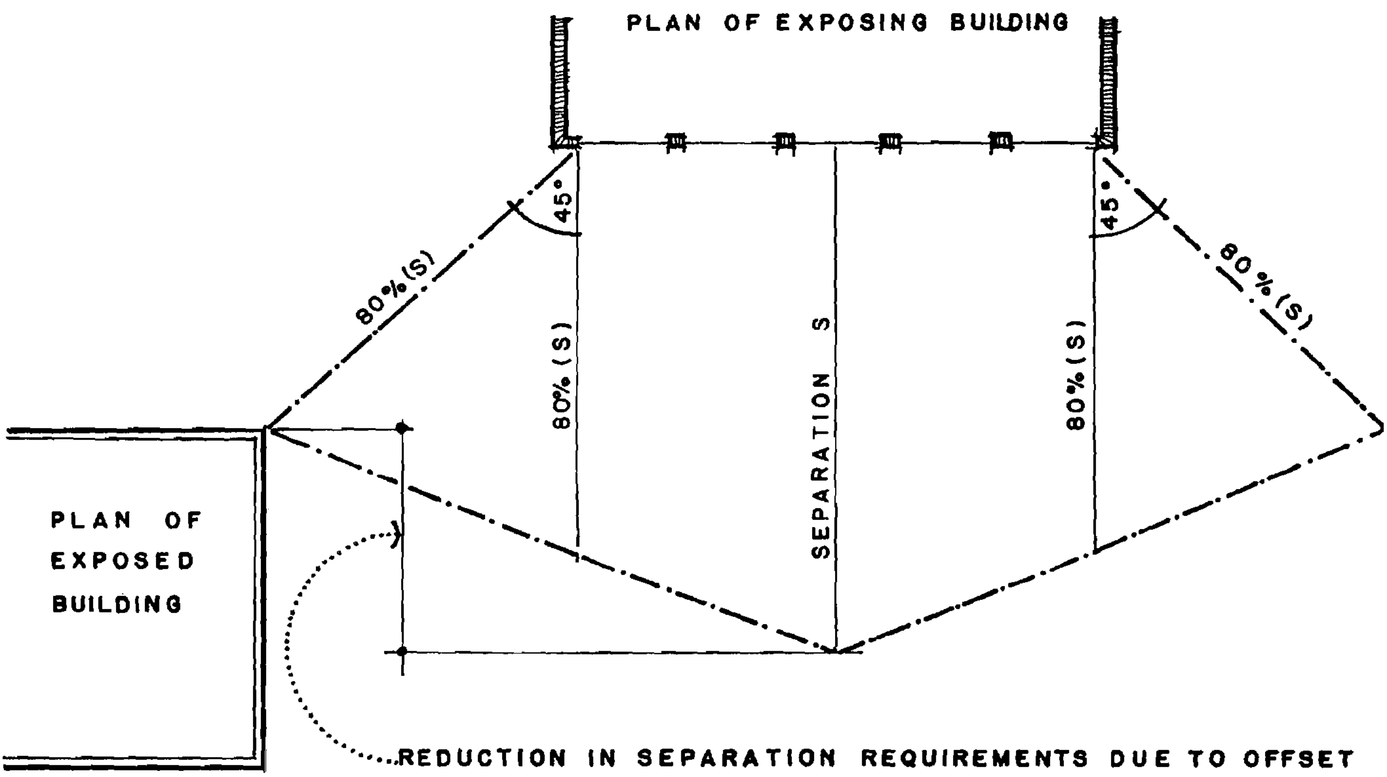

Figure 8

The first step is to analyze the buildings as before and determine the separation requirements. This allows one to see if any reduction in the separation is permissible due to the offset as shown in Figure 8.

SITUATION 4: GROUND ELEVATION

It was shown in the previous report (DBR Report 282) that a difference in the elevation of two adjacent buildings can result in a reduction of their horizontal separation requirements.

First determine the horizontal separation requirements by the usual methods. Then draw the two buildings in section showing the difference in elevation and the separations required.

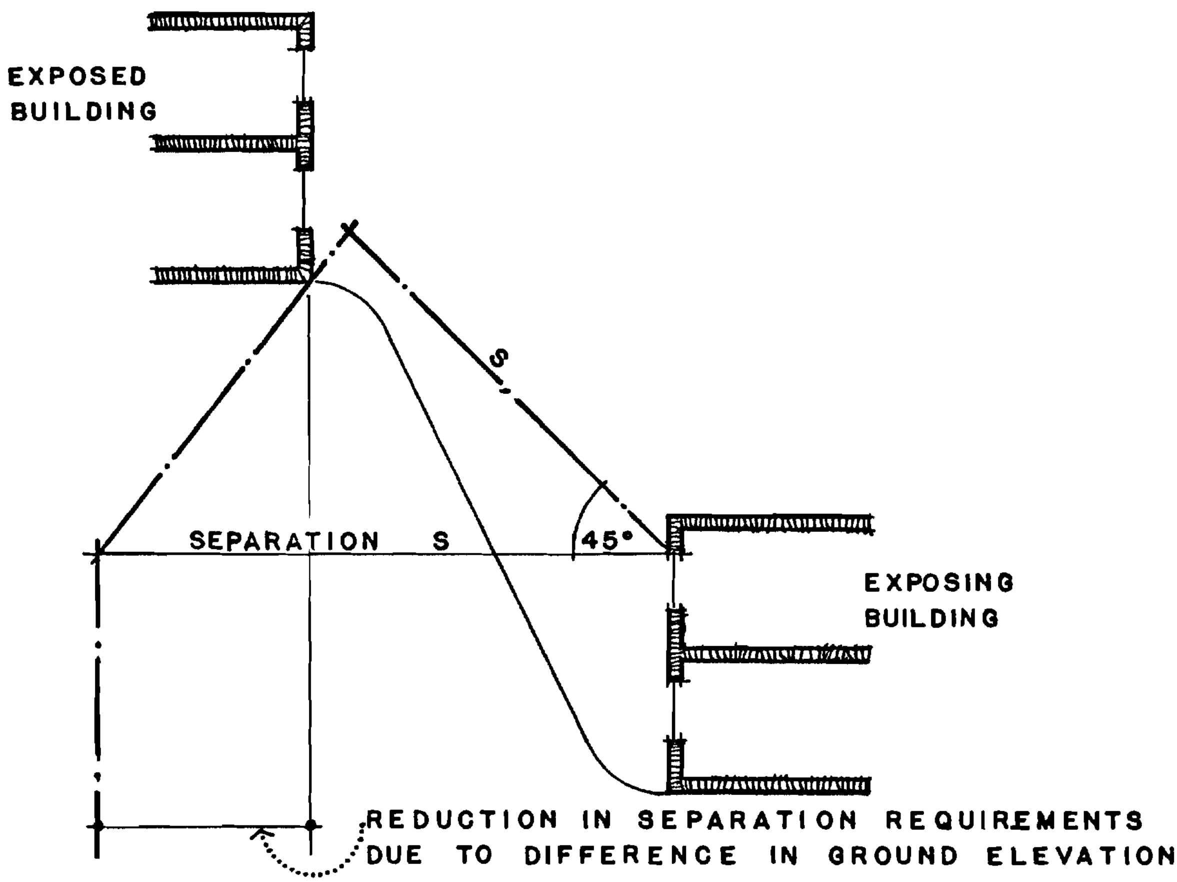

Figure 9

As before, if the exposed building lies outside the radiation envelope of the exposing building it is in no danger.

SITUATION 5: ADJACENT WALL NOT PARALLEL

The critical factor here is that the separation requirements may be reduced at the corners of the building since fire fighting has proved to be easier at these points. It is further suggested in DBR Internal Report No. 187 (20) that the separations at the corners need only be 80 per cent of the spatial separation required at the centre of the compartment under investigation. But radiation also extends in all directions. The same report makes the assumption that radiation past the corners of an opening will cease to be critical beyond a 45-degree angle. These assumptions are illustrated by Figure 10.

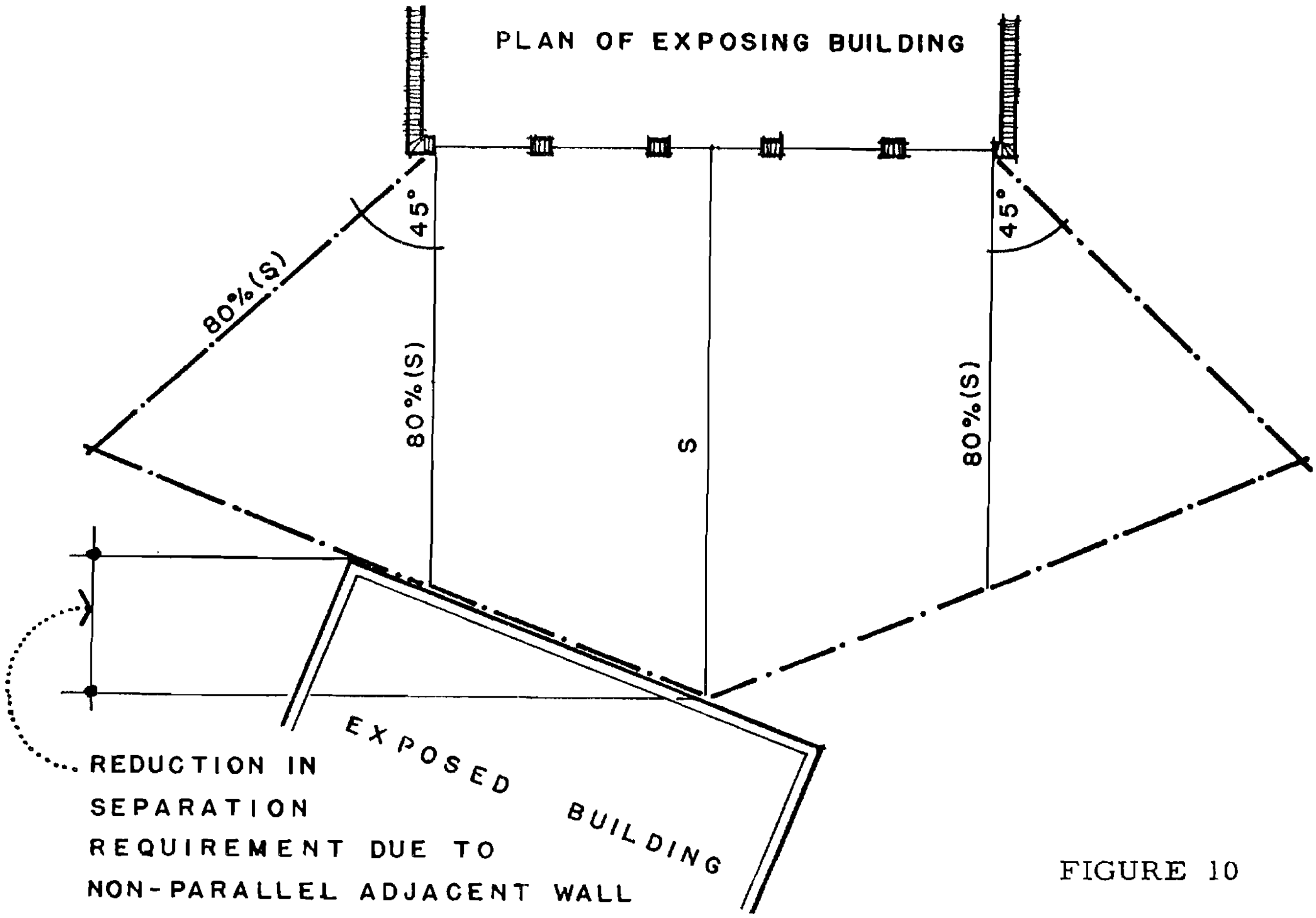

FIGURE 10

If no radiation is allowed to extend around the corners it is only necessary to ensure that there are no openings in the wall closer to the corner than a distance equal to 60 per cent of the separation distance required at the centre of the compartment.

SITUATION 6: STRUCTURAL BAFFLES

A structural baffle is a screen, fence, or similar element as distinguished from hedges, trees, or shrubs which are considered shrubbery baffles.

For a baffle to be effective in reducing the spatial separation between buildings it must have a fire resistance of at least three-quarters of an hour. That is, it should resist the radiative heat long enough for the fire department to arrive. If the barrier has a rating of less than this it will tend to facilitate the spread of fire. The effectiveness of the baffle depends on its height, length, percentage of openings, and the location and arrangement of these openings.

For purposes of explanation we consider only one building which is assumed to present the governing conditions. We also assume, for the moment, that the baffle has sufficient fire resistance and that it is imperforate. The following explanation considers three factors: the height of the baffle, the width of the baffle, and the percentage of openings in the baffle.

(a) Height of Baffle

The first step is to analyze the building to determine the spatial separation requirements neglecting the effect of the structural baffle. Since we are now concerned with the height of the baffle, the resulting space envelope is best shown by sections through the building. The next step is to place the barrier, remembering that it is assumed to be imperforate, and determine the shielding effect it offers. Figures 11, 12 and 13 show the reduction in the separation required due to this shielding.

It is shown that to effect any reduction for the full height of the building, the baffle must be at least as high as the top of the uppermost opening.

(b) Width of Baffle

The width of the baffle is analyzed in the same manner, (Fig. 12).

(c) Openings in Baffle

It is necessary to make some provision for openings in the baffle since it is unlikely that the baffle will always be imperforate and a partial screen gives some reduction in the separation required.

The method proposed can best be described by Figure 13.

This method is applicable to any percentage of openings. The example used has a uniform distribution of openings to simplify the explanation. If the openings are concentrated in one portion of the baffle, however, it is possible to use a method similar to that used in analyzing a building wall. That is, the section containing the openings create a local concentration of exposure hazard.

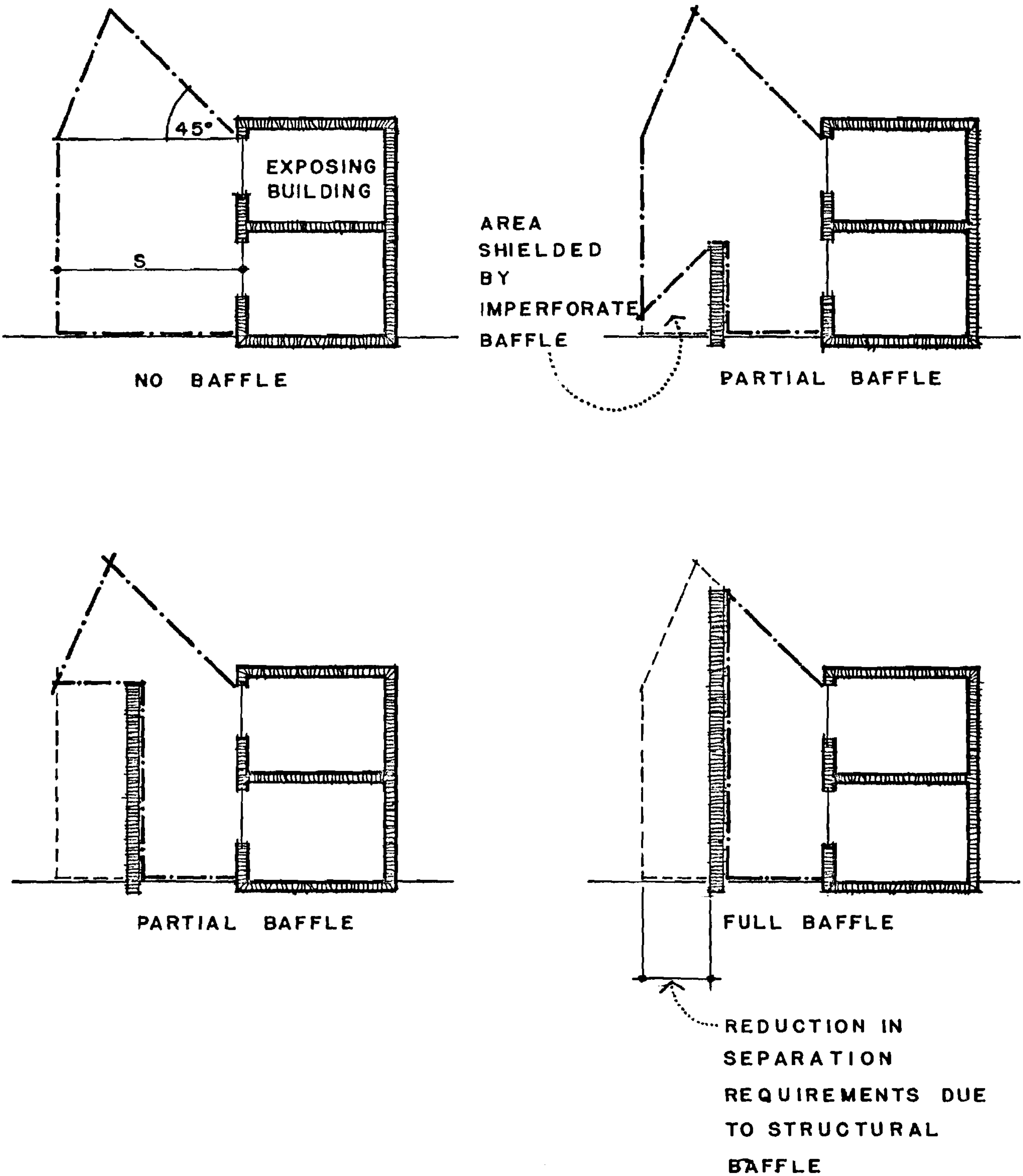
45°
EXPOSING BUILDING
S
NO BAFFLE
AREA SHIELDED BY IMPERFORATE BAFFLE
PARTIAL BAFFLE
PARTIAL BAFFLE
FULL BAFFLE
REDUCTION IN SEPARATION REQUIREMENTS DUE TO STRUCTURAL BAFFLE

FIGURE 11

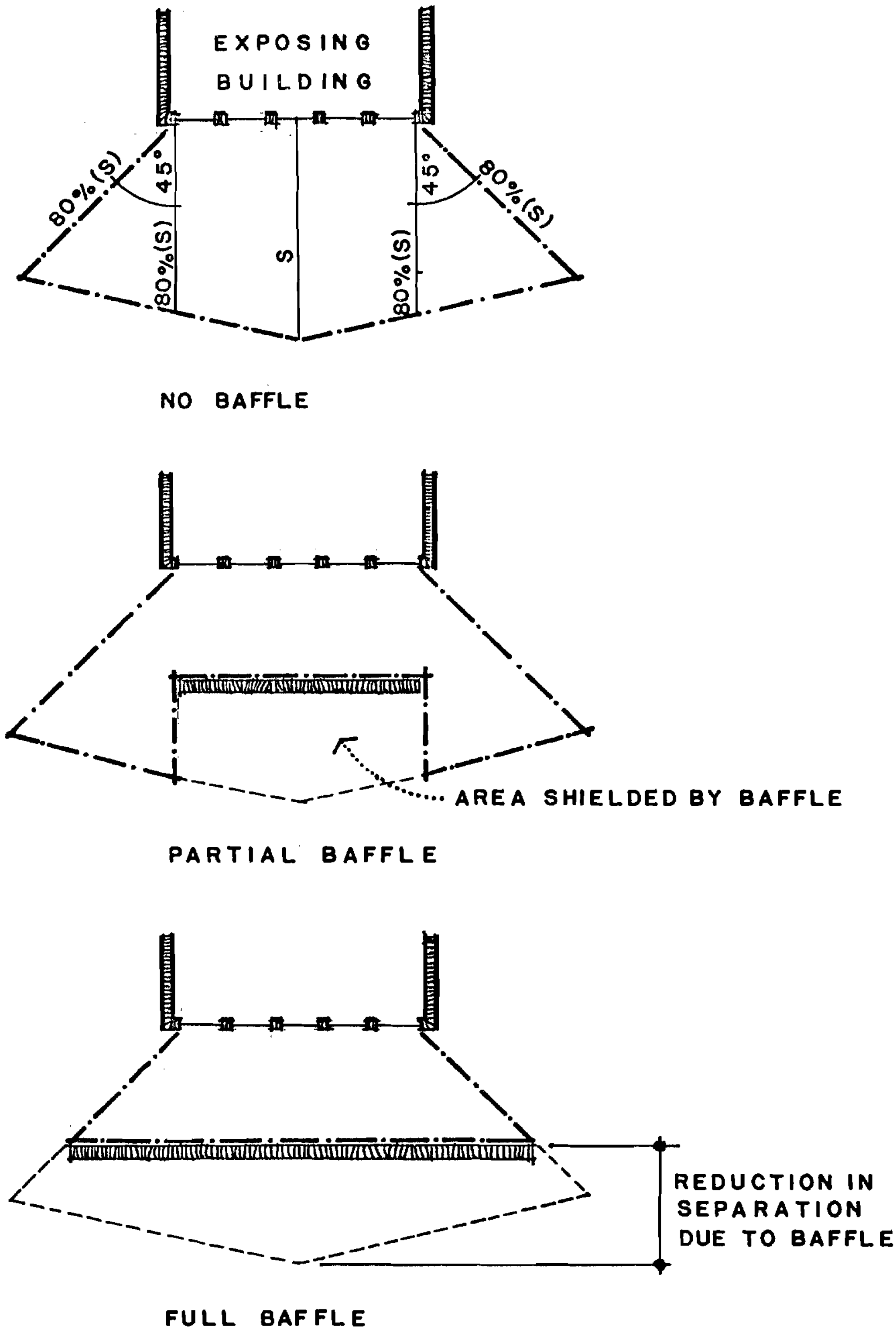
EXPOSING
BUILDING
80%(S)
45°
80%(S)
S
80%(S)
45°
80%(S)
NO BAFFLE
AREA SHIELDED BY BAFFLE
PARTIAL BAFFLE
REDUCTION IN
SEPARATION
DUE TO BAFFLE
FULL BAFFLE

FIGURE 12

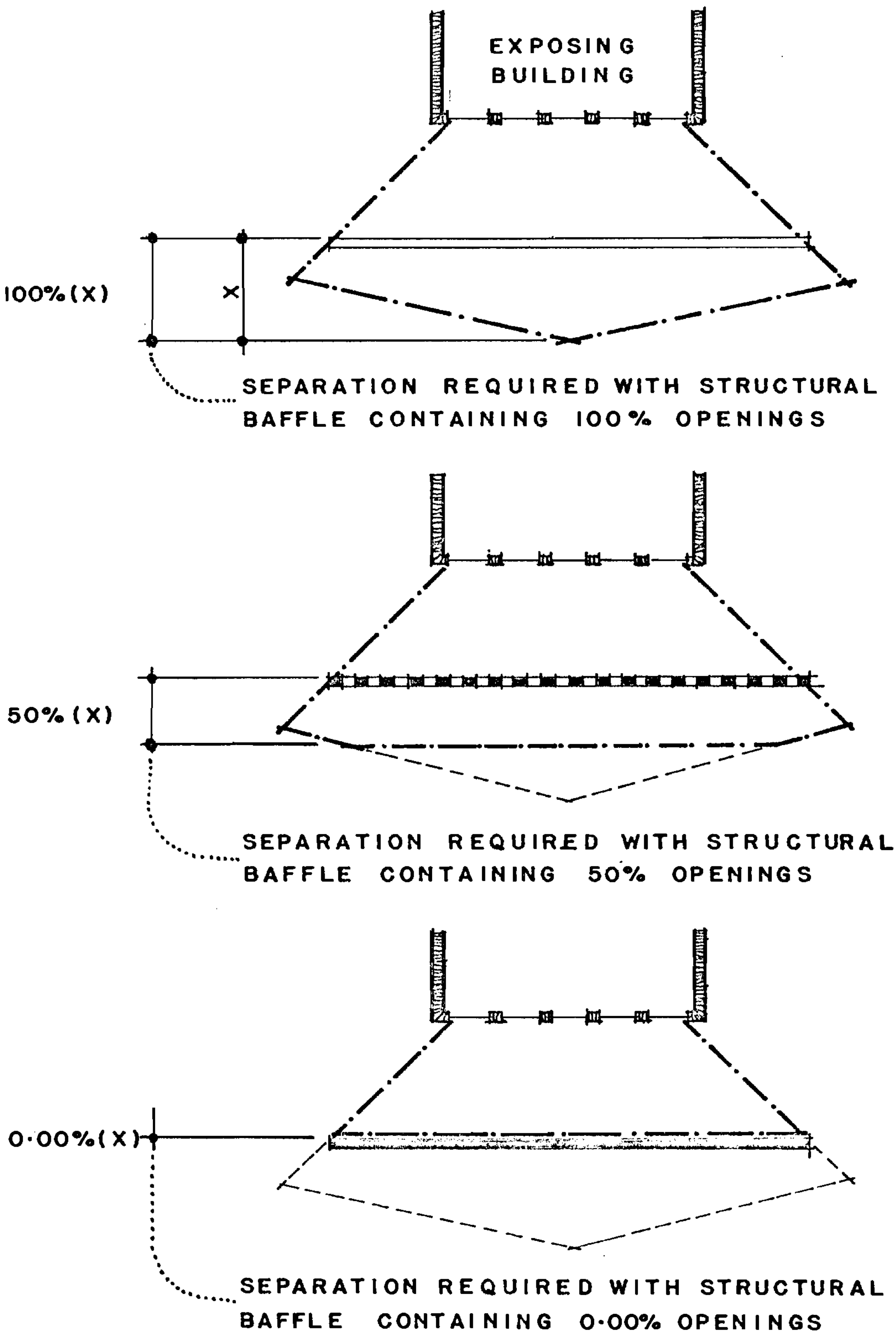
EXPOSING
BUILDING
100%(X)
X
SEPARATION REQUIRED WITH STRUCTURAL
BAFFLE CONTAINING 100% OPENINGS
50% (X)
SEPARATION REQUIRED WITH STRUCTURAL
BAFFLE CONTAINING 50% OPENINGS
0·00%(X)
SEPARATION REQUIRED WITH STRUCTURAL
BAFFLE CONTAINING 0·00% OPENINGS

FIGURE 13

PART 3

DETAILED APPLICATION OF THE FINDINGS

It is now possible to explain in more detail the method of applying the findings to particular cases. This is done through the examination of typical residential buildings the size of small apartment structures. The method of analysis outlined in the following pages can be applied to any size and shape of residential building.

The method is flexible but the technical information available makes the application of the method to small single-family dwellings difficult and, in some cases, impossible. The table of separations used does not consider wall areas of less than 30 by 10 ft and percentages of openings of less than 20 per cent. The limitations imposed on the analyses have been discussed more fully in previous reports.

OUTLINE OF THE DESIGN PROCESS

To simplify and organize the analyses, the design process is divided into stages: The following is based on the outline contained in "Fire and Space Separation" (31, p. 3) by G. J. Langdon Thomas.

Stage 1: To determine what part of the facade must be taken into account in the calculations.

Considerations:
- (a) Setback or recess of 5 ft or less from the plane of reference.
- (b) Compartmenting of the building.
- (c) Enclosed stairs.

Stage 2: To determine the area of exposure hazard.

Considerations:
- (a) Concentration of openings.
- (b) Over-all enclosing rectangle.
- (c) Enclosing rectangle.

Stage 3: To determine the separation requirements based on the risk determined by Stage 2.

Considerations:
- (a) Table of separations.

Stage 4: To locate any special area of exposure hazard which may increase or decrease the separation requirements.

Considerations:

(a) Setback in the wall of more than 5 ft.
(b) Recess of more than 5 ft with openings on 2 or 3 sides.
(c) Recess of more than 5 ft with openings in rear wall only.
(d) Non-fire-resistive projections into the space.

Stage 5: To determine the effect of special conditions.

Considerations:

(a) Height of roof.
(b) Offsets.
(c) Difference in ground elevation.
(d) Adjacent wall not parallel
(e) Structural baffles.

EXAMPLES OF DESIGN PROCESS

The following analysis proceeds from stage to stage as suggested in the above outline. Concern here is with the relationship between neighbouring buildings, therefore, to determine the spatial separation required between two buildings it is necessary to analyze both the governing factors. This is clear in the reports of Field Survey Areas Nos. 1, 2 and 3. For purposes of explanation only one building was analyzed and it was assumed that it represents the governing conditions.

The basic building used is shown in Figure 14.

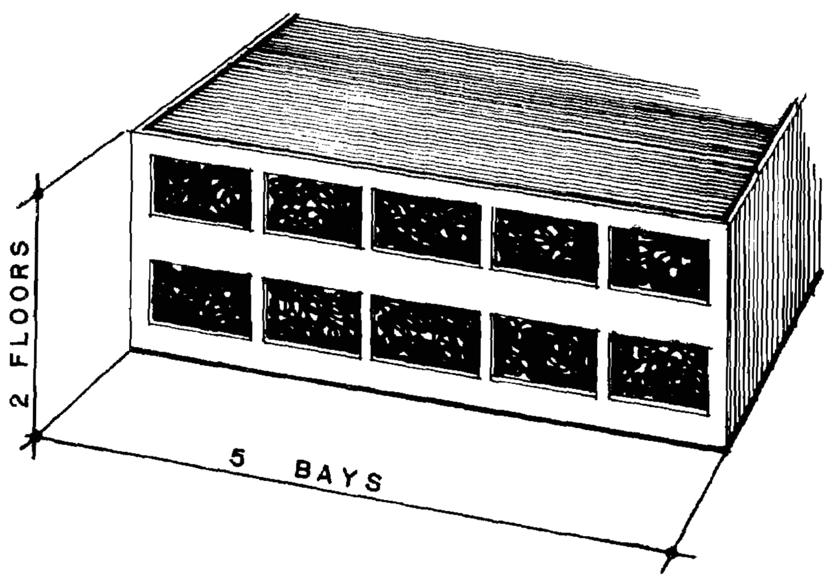

Figure 14

Figure 15 will be modified as required to illustrate the method of analysis. For example, the analyses will begin with the building shown in Figure 15.

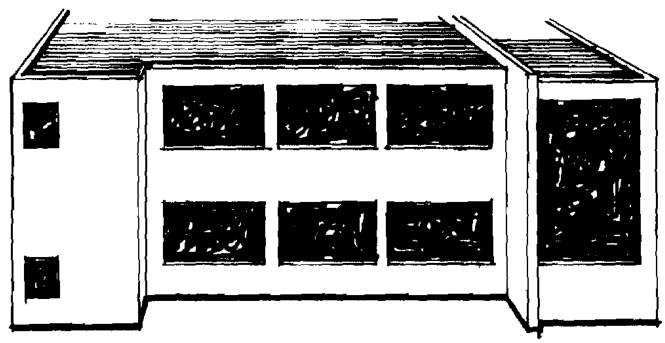

Figure 15

Stage 1: To determine what part of the facade must be taken into account in the calculations.

(a) The centre portion of the facade, since it is recessed not more than 5 ft, may be considered to lie on the planes of reference.

(b) The building is compartmented horizontally by the fire wall to the right of the recessed portion. Therefore the building may be analyzed as consisting of two portions separated by the wall.

(c) Since the staircase on the extreme right is enclosed by walls of the appropriate fire resistance, with suitable access doors, it may be ignored for the purpose of space separation calculation.

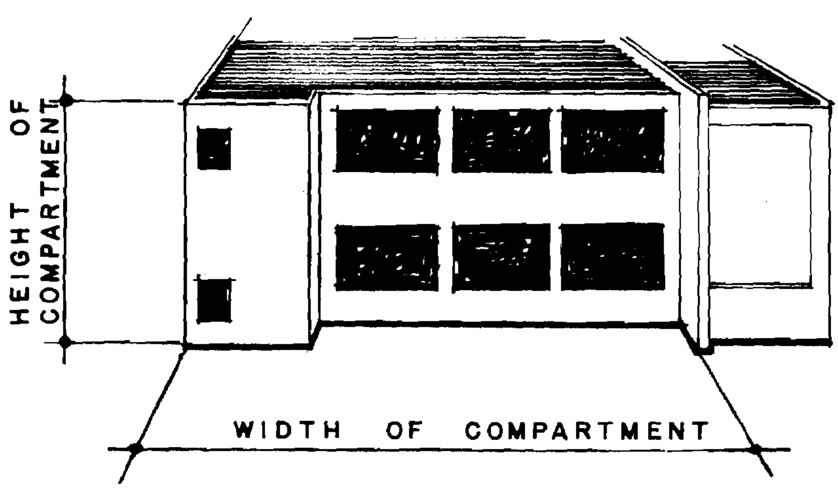

Figure 16

Stage 2: To determine the area of exposure hazard.

(a) There is a concentration of openings in the recessed portion of the facade. One method of dealing with such a condition is contained in "Housing Standards" Supplement Number 5 to the National Building Code of Canada, Section 4. 34, p. 39. (24) where it is stated:

> "Where the windows are distributed non-uniformly over the face of a building and there is a glazed area that has a width exceeding the limiting distance, the area of wall face to be considered shall be bounded by the ends of the glazed area and
>
> (a) finished grade,
> (b) a floor that is a one-hour fire separation, or
> (c) the ceiling of the uppermost floor area."

Note, however, that the "limiting distance" referred to is the separation to the lot line and hence is approximately one-half the separation from the building to its neighbouring building.

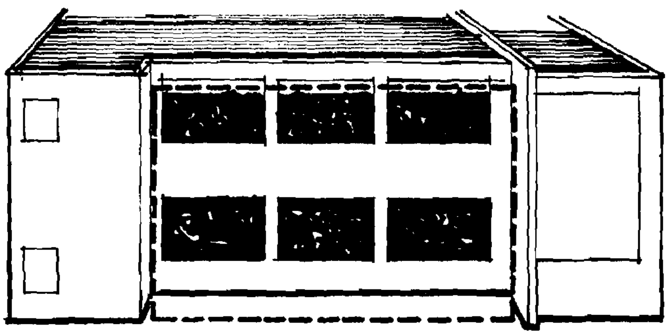

Figure 17

(b) Over-all enclosing rectangle.

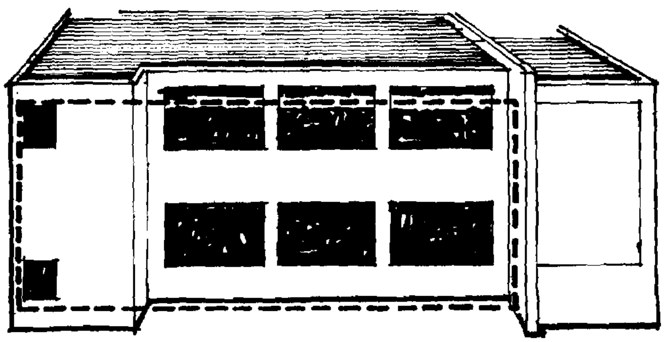

Figure 18

(c) Enclosing rectangle.

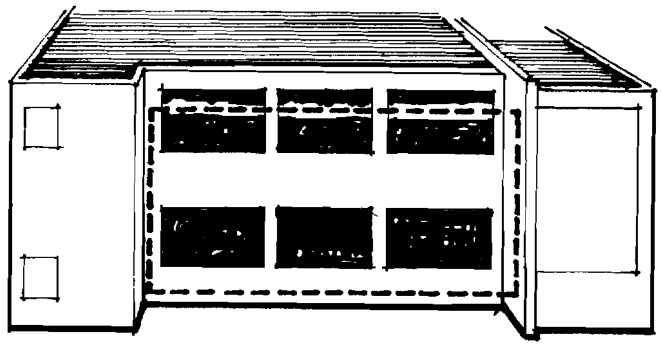

Figure 19

Stage 3: To determine the separation requirements based on the risk determined by Stage 2.

From Stage 2a:

First, determine the separation requirements for the entire portion of the facade under investigation.

Width	40 ft
Height	20 ft
Area	800 sq ft
Total area of openings	372 sq ft
Percentage of openings ($\frac{372}{800}$ x 100%).	46.5%
Separation required	36 ft

The width of the glazed area exceeds one-half this distance, therefore:

Width	30 ft
Height	20 ft
Area	600 sq ft
Total area of openings	360 sq ft
Percentage of openings ($\frac{360}{600}$ x 100%).	60%
Separation required.	37 ft

From Stage 2b:

Width	40 ft
Height	15 ft
Area	600 sq ft
Total area of openings	372 sq ft
Percentage of openings	62%
Separation required	37 ft

From Stage 2c:

Width	30 ft
Height	15 ft
Area	450 sq ft
Total area of openings	360 sq ft
Percentage of openings	80%
Separation required	36 ft

If these were the only considerations, the total separation required between this building and its neighbour would be the maximum value of 37 ft.

Stage 4: To locate any special area of exposure hazard which may increase or decrease the separation requirements.

(a) Setback in the wall of more than 5 ft.

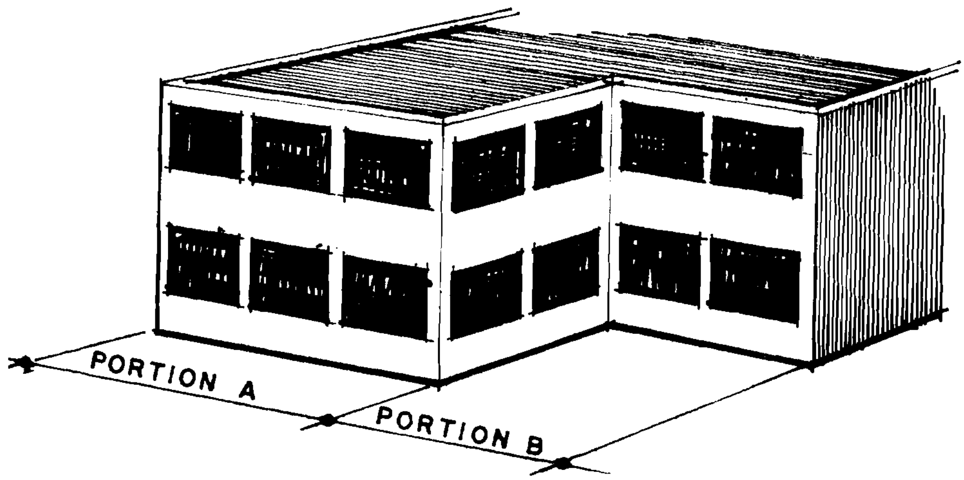

Figure 20

The method of solving this problem is to consider the facade in two portions: the part on the plane of reference, and the part set back from the plane of reference. The first portion may be analyzed normally. The setback portion requires substitution of an "equivalent radiator" as shown in Figure 21. The openings in the recess are assumed to lie on this equivalent radiator and the separation requirements are assessed as before.

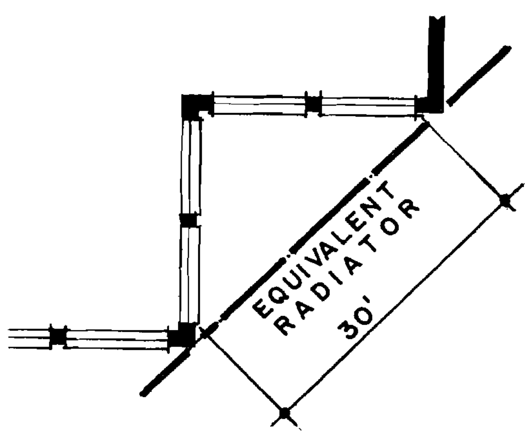

Figure 21

Assuming Stages 1, 2 and 3 have been completed for this building:

Portion A:

Width	30 ft
Height	20 ft
Area	600 sq ft
Total area of openings	360 sq ft
Percentage of openings	60%
Separation required	37 ft

Portion B:

Width	30 ft
Height	20 ft
Area	600 sq ft
Total area of openings	480 sq ft
Percentage of openings	80%
Separation required	43 ft

The final separation requirement is shown in Figure 22. It is assumed that the radiation does not extend around the corner, in any appreciable amount, beyond a 45-degree angle as shown.

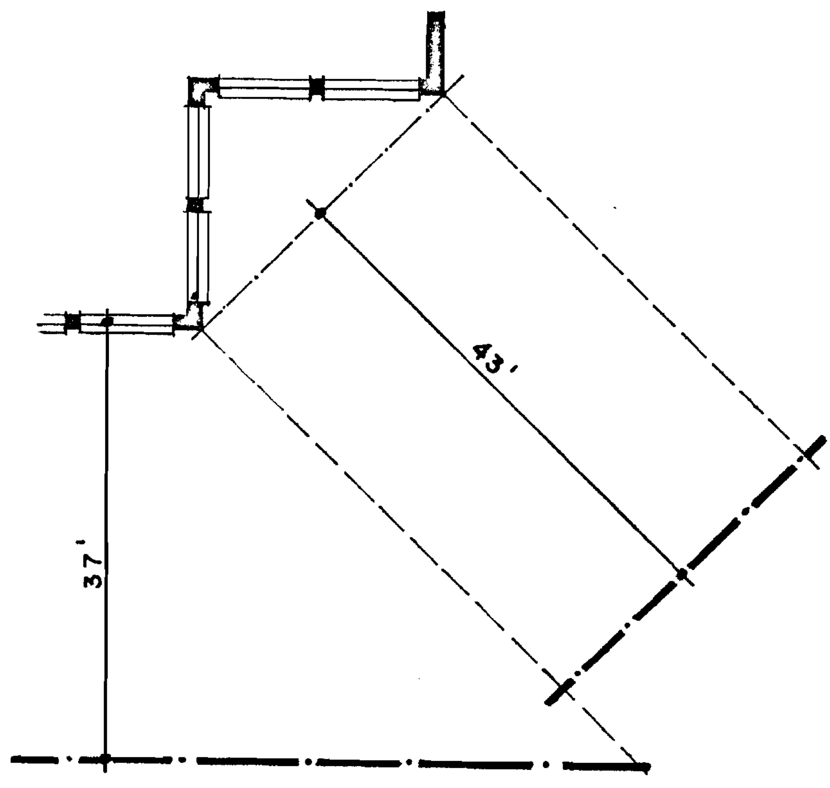

Figure 22

(b) Recess of more than 5 ft with openings on two or three sides: all openings in the facade are considered to be radiating at the plane of reference.

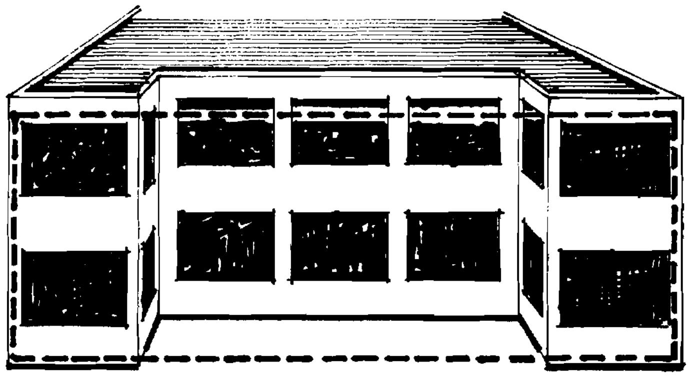

Figure 23

Width	50 ft
Height	20 ft
Area	1000 sq ft
Total area of openings . . .	840 sq ft
Percentage of openings $(\frac{840}{1000} \times 100\%)$	84%
Separation required	56.4 ft

(c) Recess of more than 5 ft with openings in rear wall only. The first separation requirement should be obtained by assuming that all openings are radiating at the aperture. This may then be reduced by means of a formula because some openings are behind the plane of reference and tend to reduce the intensity at the plane.

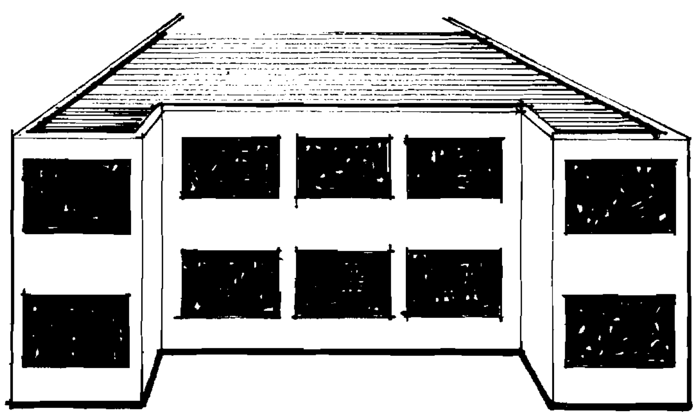

Figure 24

Determine the first separation requirement:

Width	50 ft
Height	20 ft
Area	1000 sq ft
Total area of openings	600 sq ft
Percentage of openings	60%
Separation required	47 ft

The area of the openings in the recess may be reduced by the factor:

$$\left(\frac{s}{s + r}\right)^2 = \left(\frac{47}{57}\right)^2 = 0.72$$

The area of the openings on the plane of reference = 240 sq ft; the area of the openings in the recessed portion = 360 sq ft. The area of the openings in the recess may then be considered to be 0.72 (360) = 260 sq ft.

The total area of openings is = 260 + 240 = 500 sq ft.

Percentage of openings $= \frac{500}{1000} \times 100\% = 50\%$

Separation required . . . . 42 ft

(d) Non-fire-resistive projections into the space.

This condition is dealt with by assuming that a non-fire-resistive projection from the exposing building into the spatial separation will not constitute a hazard if it is 4 ft or more from the exposed building.

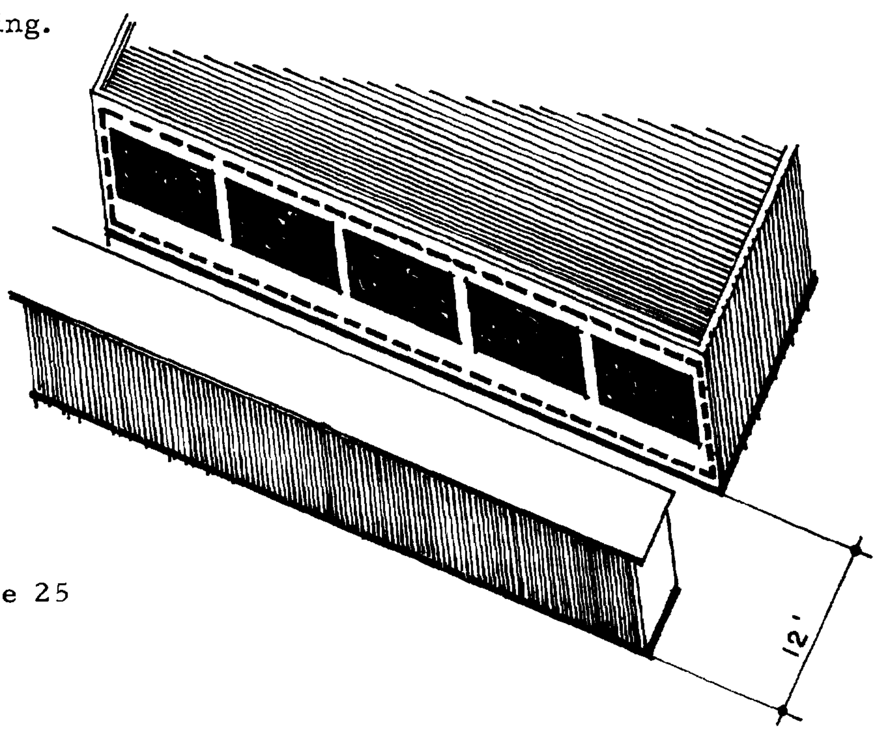

Figure 25

Width	40 ft
Height	10 ft
Area	400 sq ft
Total area of openings	80 sq ft
Percentage of openings	20%
Separation required	13 ft

The projection, however, extends 12 ft from the wall. Therefore the separation required is 12 ft + 4 ft = 16 ft rather than 13 ft as determined by the calculations.

Stage 5: To determine the effect of special conditions

(a) Height of roof

This is best shown by using two examples:

The first dealing with roof openings which lie on the plane of reference, and the second with openings set back from the plane of reference.

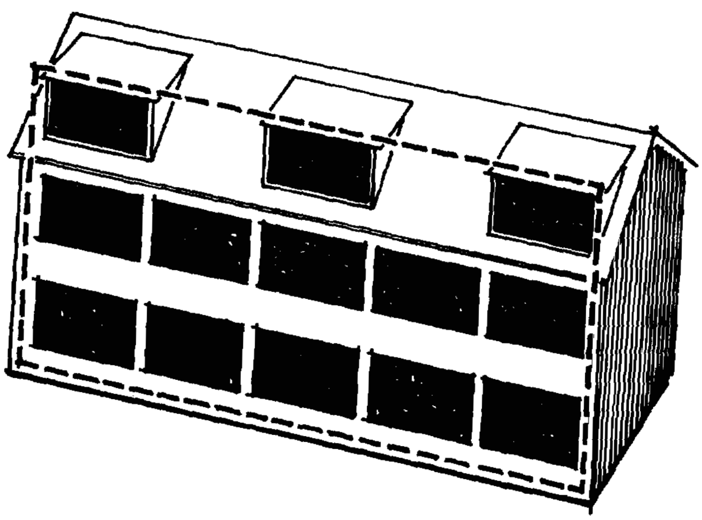

Figure 26

Width	50 ft
Height	30 ft
Area	1500 sq ft
Total area of openings	750 sq ft
Percentage of openings	50%
Separation required	53 ft

The second example is analyzed as a setback in the wall.

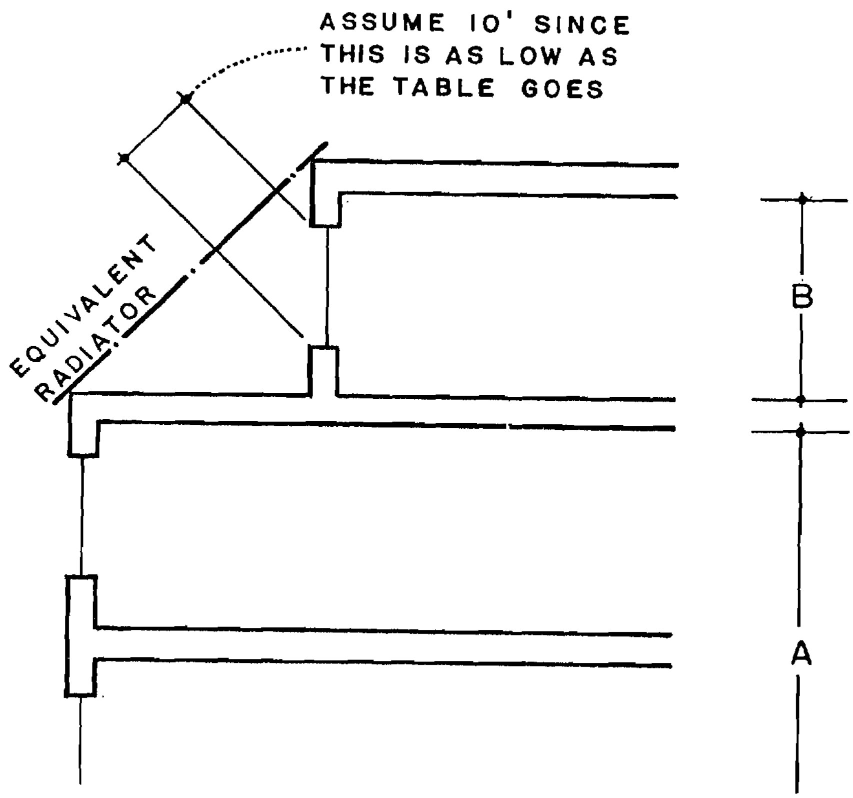

Figure 27

Portion A:

Width	50 ft
Height	20 ft
Area	1000 sq ft
Total area of openings	600 sq ft
Percentage of openings	60%
Separation required	47 ft

Portion B:

Width	50 ft
Height	10 ft
Area	500 sq ft
Total area of openings	180 sq ft
Percentage of openings	36%
Separation required	21 ft

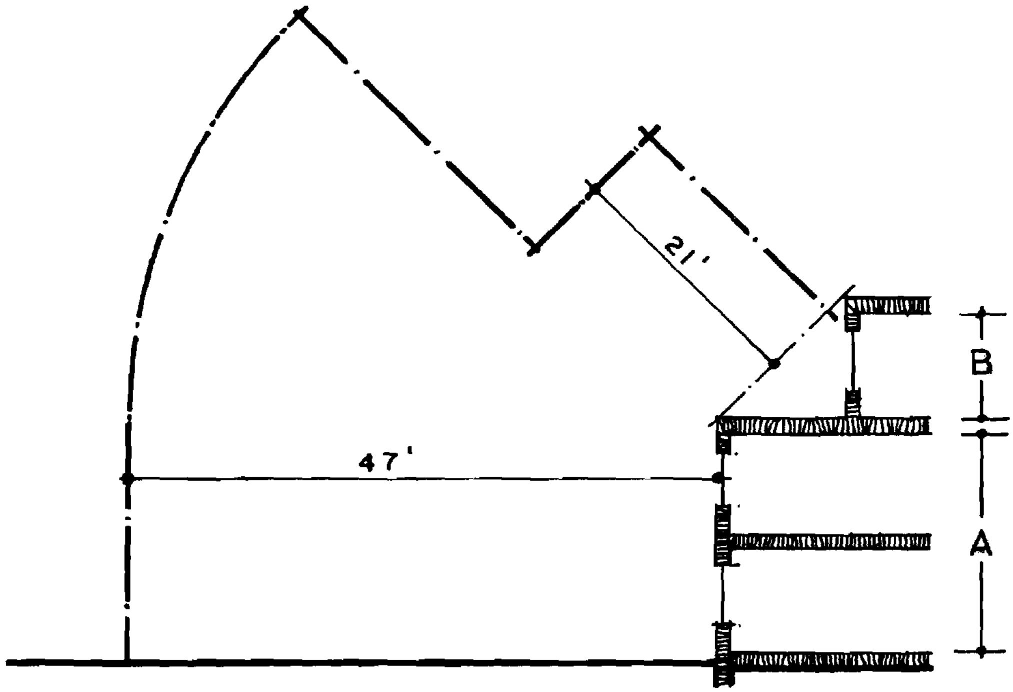

Figure 28

(b) Offsets

It was mentioned that a reduction of the separation requirements is permissible at the corners of a building. First, determine the boundary as before:

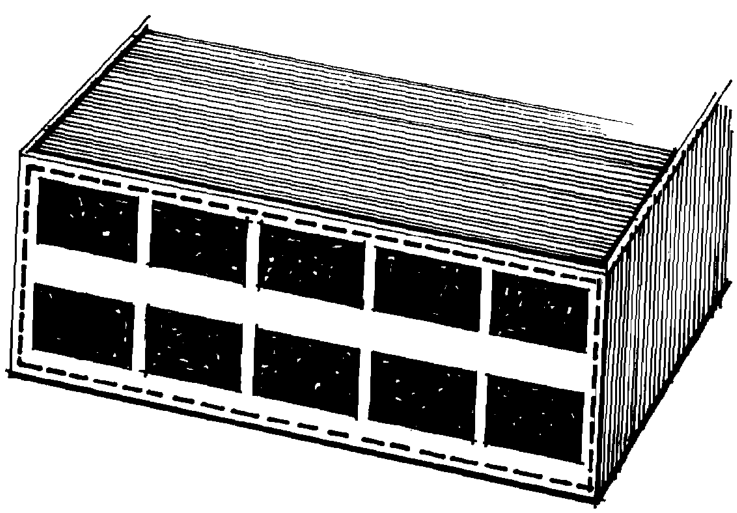

Figure 29

Width	50 ft
Height	20 ft
Area	1000 sq ft
Total area of openings	600 sq ft
Percentage of openings	60%
Separation required	47 ft

Then, reduce the separations at the corners as shown in Figure 30.

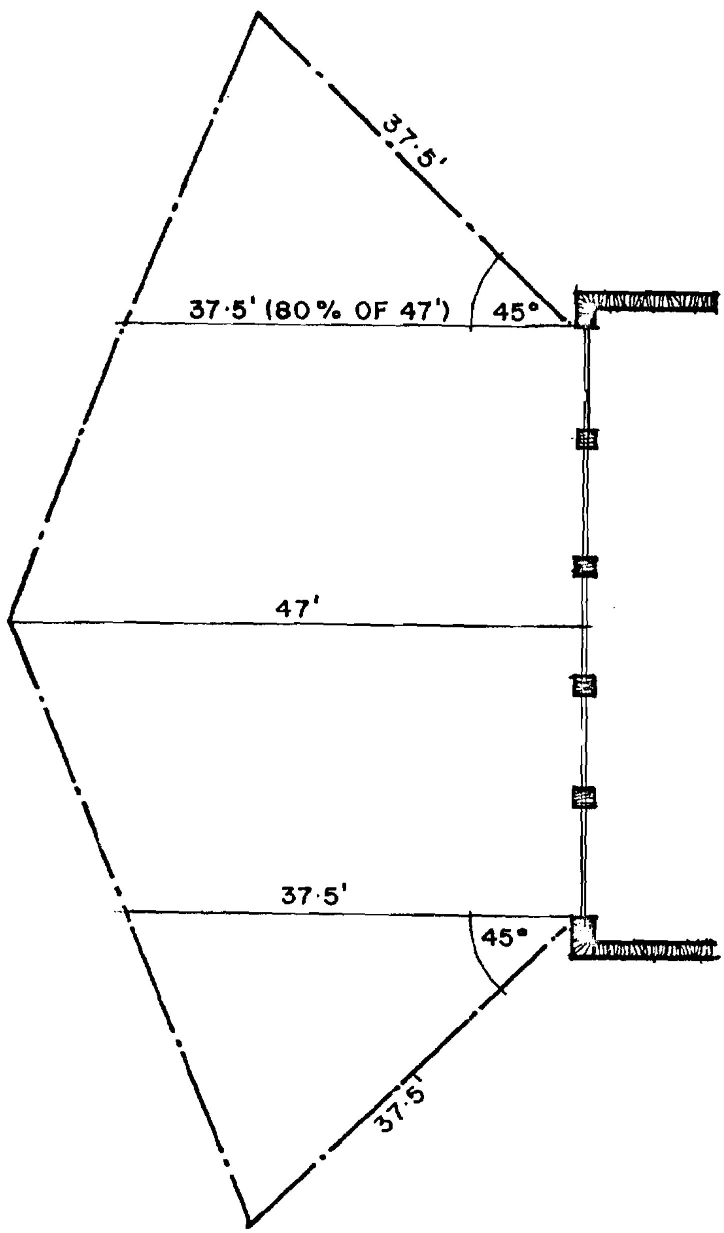

Figure 30

This means that two buildings offset in relation to each other may, for example, be sited as follows:

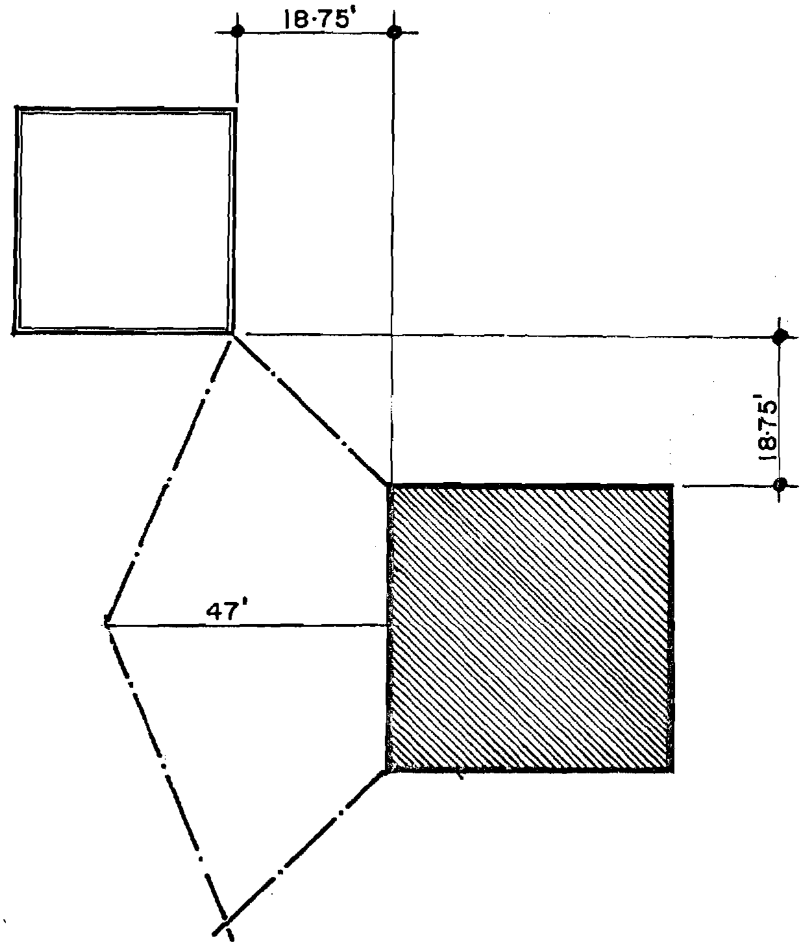

Figure 31

It is seen that the separation perpendicular to the facing walls is now 18.75 ft as opposed to the 47 ft previously required.

(c) Difference in ground elevation

First, analyze the building as before.

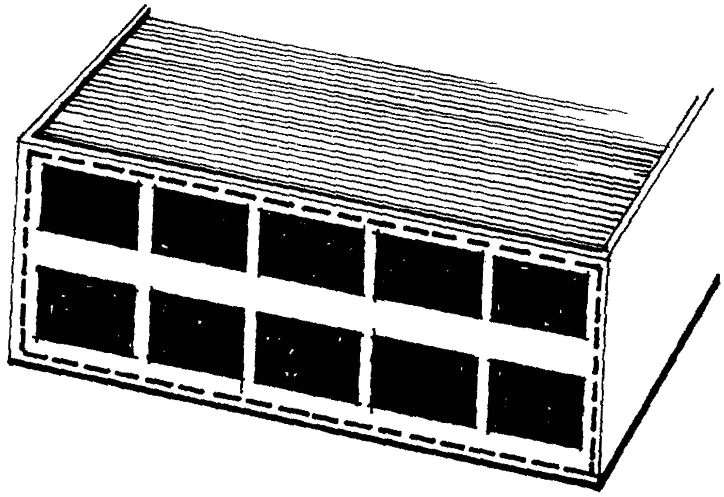

Figure 32

Width	50 ft
Height	20 ft
Area	1000 sq ft
Total area of openings	600 sq ft
Percentage of openings	60%
Separation required	47 ft

It is seen in Figure 33 that a difference in ground elevation reduces the horizontal separation required between buildings.

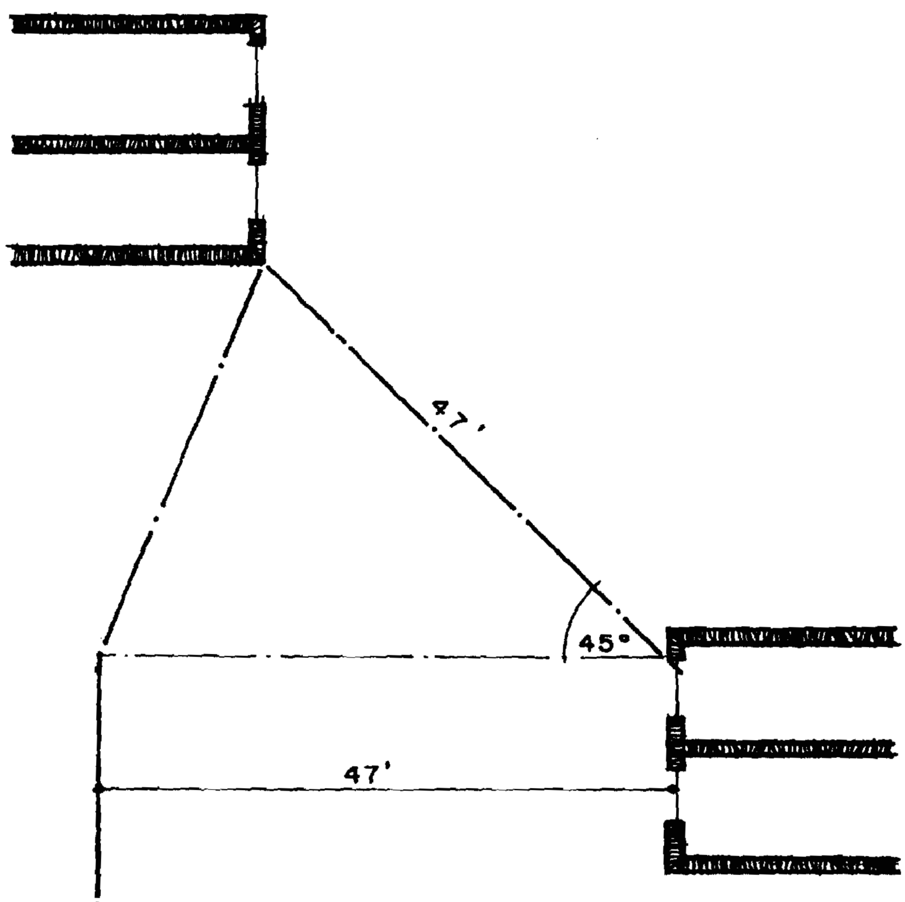

Figure 33

(d) Adjacent wall not parallel

Previous analyses show that a reduction of the separation requirements is possible at the corners of the building.

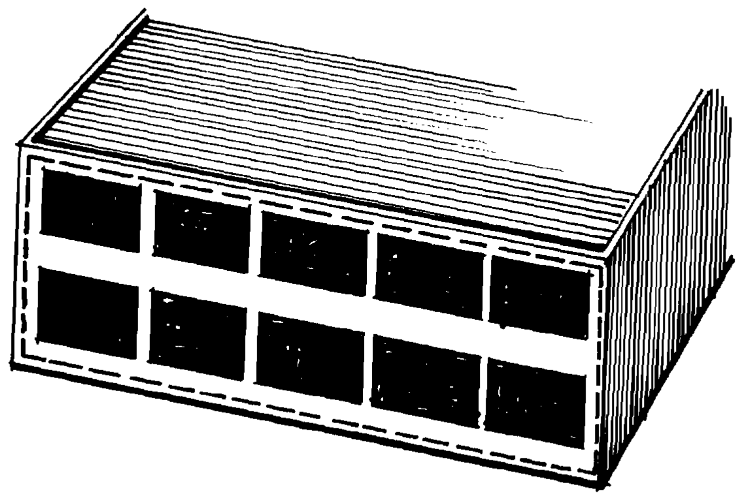

Figure 34

Width	50 ft
Height	20 ft
Area	1000 sq ft
Total area of openings	600 sq ft
Percentage of openings	60%
Separation required	47 ft

Assuming this building to be the governing one, the buildings may be sited as shown in Figure 35.

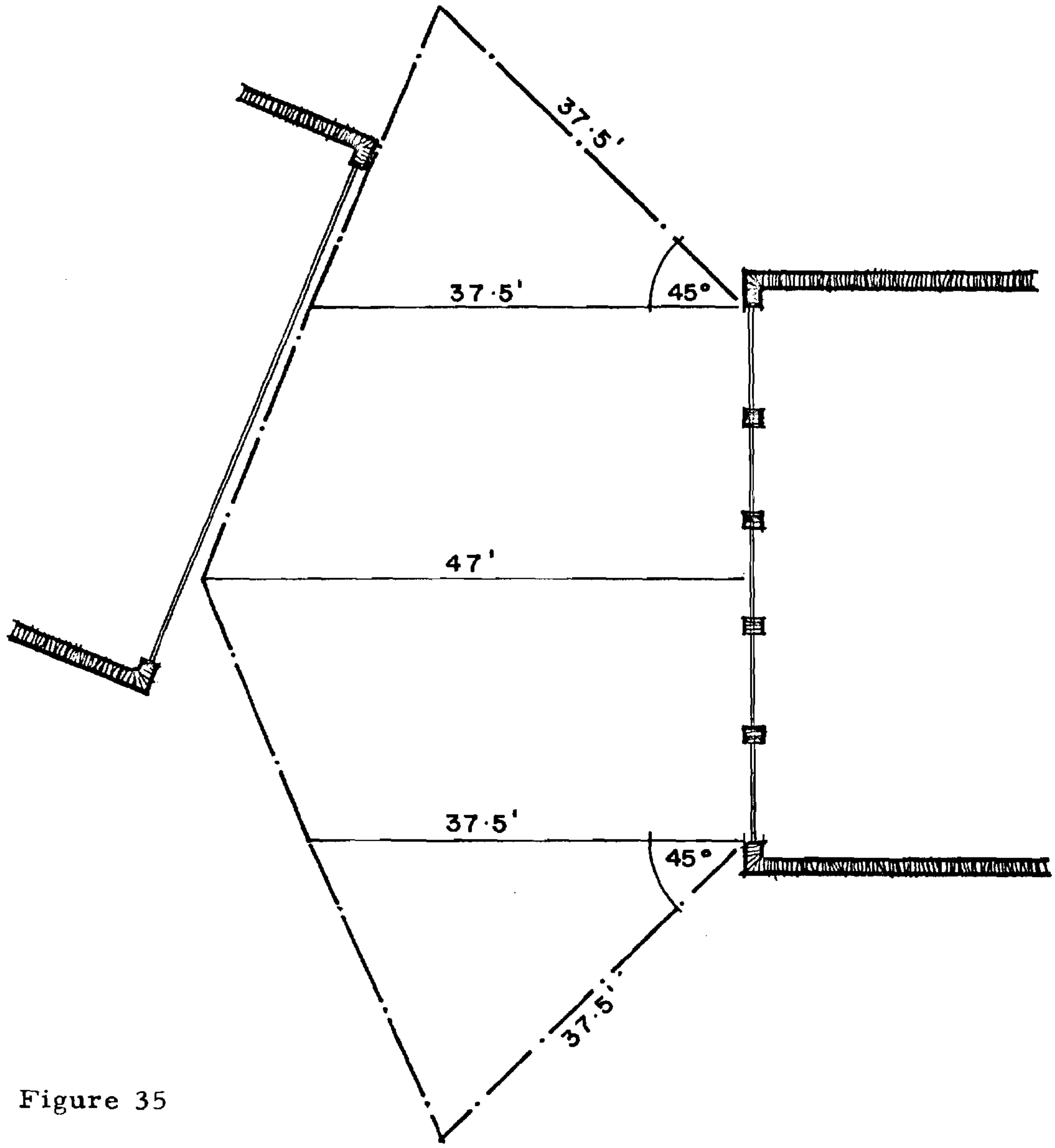

Figure 35

(e) Structural baffles

First, analyze the building as before.

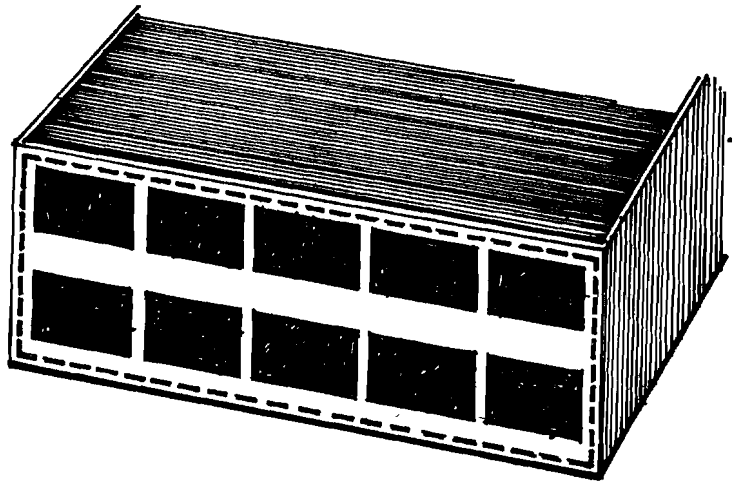

Figure 36

Width	50 ft
Height	20 ft
Area	1000 sq ft
Total area of openings	600 sq ft
Percentage of openings	60%
Separation required	47 ft

The barrier is of fire-resistive materials and has 33 per cent openings distributed uniformly. The full separation must be maintained where the barrier provides no shielding. A reduction is possible in the area protected by the barrier.

Separation required for Portion A . . . . 47 ft

Separation required for Portion
B = 33% x 27 ft . . . . 29 ft

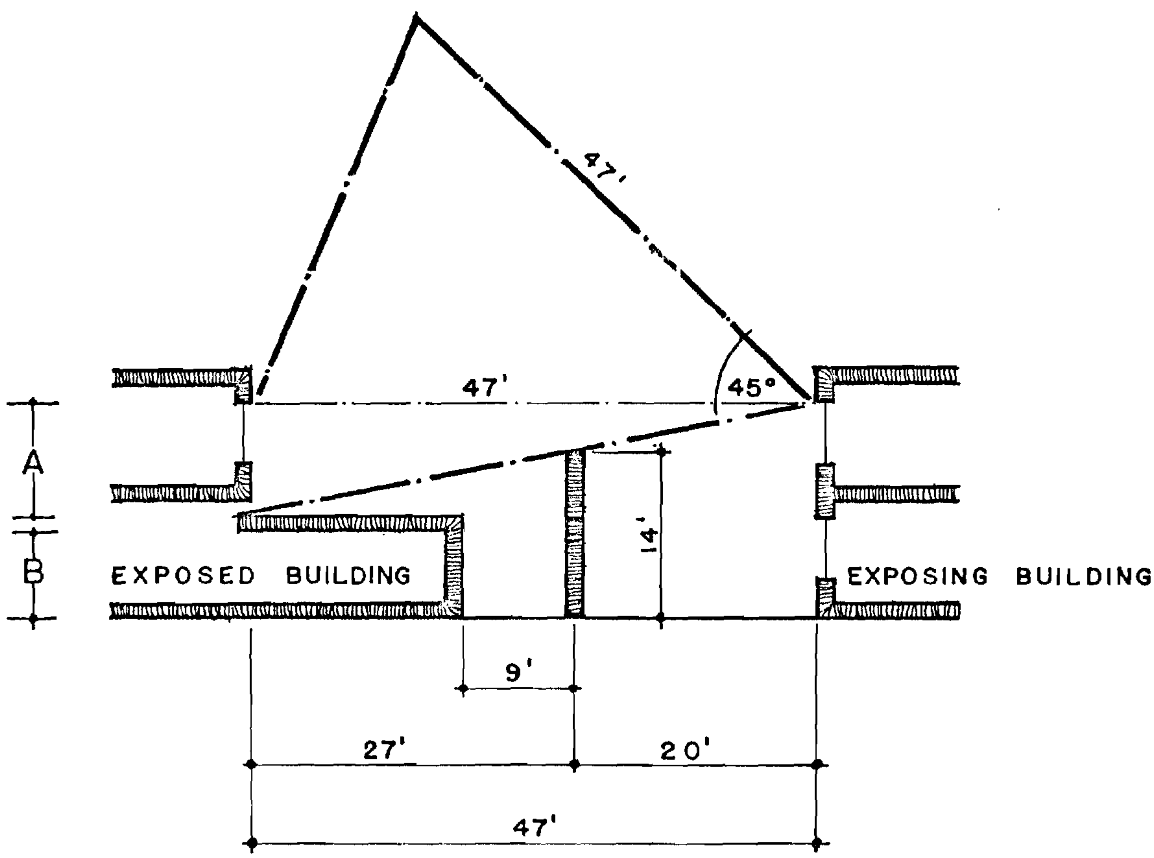

Figure 37

CONCLUDING REMARKS

This report concludes the study of fire regulations and the first special study made as part of the larger project "Performance Standards for Space and Site Planning for Residential Development." This project encompasses broad objectives and a wide scope of interest. A brief review of progress to date is included here to relate the specific conclusions to the general objectives.

In the Preface to the main report (DBR Internal Report No. 273) the late Professor Lasserre wrote - "The rigidity of current regulations and the limitations they place on the production of variety in the layout of residential areas has been of much concern to planners, architects, and social scientists. This concern prompted the School of Architecture at the University of British Columbia to arrange with the Division of Building Research of the National Research Council to carry out an investigation into the criteria that might determine space standards, facilitating greater variety in the layout of residential buildings."

The main report set the scene for the more precise studies. It identified fire, daylight, air, noise, privacy view, traffic and outdoor space as community objectives and it identified the dimensions which are critical if outdoor space is to be controlled. Finally it expressed the hope that after further more concentrated studies it would be possible to evaluate these dimensions and particularly to evaluate the effect of an increase or decrease in any one of the dimensions in terms of fire, light and the other community objectives.

For example, one of the critical dimensions was building offsets. A balcony might be interpreted in this class. The balcony might reduce the space between buildings and so increase the risk of fire spread but this might be a matter of small importance to fire spread compared with say, the size of window opening. On the other hand, a balcony might be of major amenity importance and so be very favourably assessed from the viewpoint of privacy, view and space. In considering all the community objectives together, a design with balconies might pass because it enhances the general good whereas a rigid separate uncompromising approach could condemn the design unnecessarily from the fire or some other single point of view.

Some may liken this to a form of horse-trading and claim that it has no place in building regulations. This is not necessarily so. One fire precaution, for example, permits building area to be doubled if a sprinkler system is installed even though the sprinkler system is not connected directly with the increase in the risk. There is precedent then for trading but of a unilateral kind. So far there is no precedent for the kind of multilateral trading (providing health benefits to counter fire risks) that is suggested here.

Yet safety is never absolute. A regulation is always a balance between economy and safety and there is always the possibility that, for the sake of convenience or economy, certain safety regulations might be relaxed. This circumstance actually occurs in some building law. It is a principle of building safety that there should be two means of escape for the occupants of a building. Many building by-laws using an eminent authority, the NFPA Exits Code, as a precedent permit "dead-end" corridors of a limited length from which there is only one means of escape. This law which requires two exits for some people and only one for others does so for reasons of economy and convenience. The time may come when the balance of safety and economy may make it advisable to consider the eight functional determinants, identified by this study all together in connection with any or all dimensional limitations.

It was with this hope as a stimulus that the survey of the three blocks in Vancouver was made. This detailed study has proved rewarding and even though it is only the first of this series and limited to the fire aspect there are some conclusions worth recording. As might be expected these have to do with space controls from the viewpoint of fire spread.

The conclusions resulting from this study are of three kinds:

1. An appraisal of existing controls;
2. Some suggestions for improvement of the National Building Code; and
3. A suggested grading of space dimensions referred to in controls for fire spread.

CONCLUSIONS

1. Appraisal of Existing Controls

(a) A principal observation of architects in their everyday practice is that yard restrictions and setbacks are so inflexible as to inhibit design. Internal Report No. 273 quotes the RAIC Committee of Enquiry on Residential Environment as saying "Where municipal codes governing physical development are demonstrably linked to such future contingencies, their clauses must be respected. But this sensible linkage is hard to discover in many of the by-law restraints put upon residential area design."

The detailed study of three blocks in Vancouver supports these views. Using the best available standard to measure safe distance separations, it was found that in none of the three blocks did the separation between buildings correspond to the distances which were calculated to be necessary. The actual distances were neither consistently higher nor consistently lower. They were much too low for safety in downtown Vancouver and higher than necessary in the suburbs.

It is clear that yard restrictions have so far failed to provide safety measures corresponding to the hazards which exist. It seems clear from the evidence that the main forces which result in space around buildings are those of custom and human desires, modified by economics. The effect of fire regulations has been to alter these spaces slightly but not enough to be significant as a serious fire measure. In many instances, both in centre town and suburban districts, adequate fire safety could be obtained easily with a suitable common wall. For reasons of custom and taste such a solution is prohibited and a distance separation is required. Economics operate to close this separation and fire safety operates to open it. Until the recent issues of the National Building Code of Canada were published, however, there had been no bylaw or reference law* which relates this space to the hazard.

(b) The present system is inflexible. The calculated safe distance varies with every variation in design but this is not reflected in the requirements which demand a uniform setback along the street. It is remarkable that, while most modern building regulations permit an almost infinite variety of material and form, yard and setback regulations are inflexible in the extreme.

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* In 1928 the Village of Rockcliffe Park, Ontario, passed a bylaw requiring that accessory buildings be constructed of impervious fire-resistive construction unless they were situated at least 20 feet from the lot line.

Because of the wide variation in the calculated space requirements for prevention of fire spread, the yard or setback requirements which are enforced only rarely represent a correct minimum. For some buildings the setback is not enough and so permits a serious hazard. For others it is too much and so imposes an unjustified restraint on design.

2. Some Suggestions for Improvement in the National Building Code

The National Building Code requirements to prevent fire spread and some more basic references formed the performance standard by which the three city blocks were judged. This careful assessment proved not only to be revealing regarding the city blocks and the regulations under which they were built but also with regard to the National Building Code performance requirements. It was the first time that these provisions had been given a rigorous test and some shortcomings were revealed. These mostly involved refinements which had been put aside by the Associate Committee until the general concept of the regulations had been accepted. The survey of the city blocks proved the soundness of the performance standard but revealed difficulties which can be overcome with further study and experience. Part 2 of this report offers precise solutions to the problems which are likely to arise. This can serve as a useful guide to architects and building inspectors faced with administering these requirements in the field and also to the Associate Committee on the National Building Code for future revision work.

3. A Suggested Grading of Space Dimensions

In DBR Report 273 a pro-forma was presented (Figure 30) as a suggested method of comparing the physical design factors of a building exposure against the objectives to be sought in building control. This pro-forma is reproduced as Figure 38 in this report. Figure 39 is a modified version which includes only those matters of concern to fire safety.

Although it is not possible yet to assign values in this performance table what can be done now is to give a suggested weighting and hierarchy of the design factors within the basic consideration of safety against the spread of fire. These are, of course, entirely subjective and are based on the results of the study of the three field survey areas. The categories are listed below in order of their importance.

PERFORMANCE TABLE

DESIGN FACTORS		COMMUNITY OBJECTIVES A FIRE	B DAYLIGHT	C AIR	D NOISE	E PRIVACY	F VIEW	G TRAFFIC	H OUTDOOR SPACE	BONUS / PENALTY	TOTAL SCORE
1	HEIGHT OF WALL										
2	LENGTH OF WALL										
3	AREA OF WINDOWS										
4	HEIGHT OF ROOF										
5	SHAPE OF ROOF										
6	VOLUME OF STRUCTURE										
7	SPATIAL SEPARATION										
8	SETBACKS & OFFSETS										
9	GROUND ELEVATION										
10	ADJACENT WALL NOT II										
11	STRUCTURAL BAFFLE										
12	SHRUBBERY BAFFLE										
	BONUS / PENALTY										
	TOTAL SCORE										

FIGURE 38

PERFORMANCE TABLE

		A FIRE
1	HEIGHT OF WALL, LENGTH OF WALL AND AREA OF OPENINGS	
2	HEIGHT OF ROOF	
3	OFFSET	
4	GROUND ELEVATION	
5	WALL NOT PARALLEL	
6	STRUCTURAL BAFFLE	

FIGURE 39

1. Category 1: Height of wall, length of wall and percentage of openings. A given variation in the design elements has a relatively large effect on the spatial separation required.

2. Category 3: Offsets.

3. Category 2: Height of roof.

4. Category 5: Adjacent wall not parallel. These three categories (Nos. 4, 5, and 6) are about equal in importance. A given variation in the design elements has a relatively moderate effect on the separation required.

5. Category 6: Structural baffles.

6. Category 4: Difference in ground elevation. These last two categories are also of about the same weight. A given variation in the design elements has a relatively small effect on the spatial separation.

With some caution, the following weighting of the categories as a point of departure for the future compilation of the bonuses and penalties for the system is suggested.

Category 1:	10 points
Category 3:	6
Category 2:	5
Category 5:	4
Category 6:	1
Category 4:	1

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